



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> :

G06F 15/42

A2

(11) International Publication Number:

WO 95/23378

(43) International Publication Date:

31 August 1995 (31.08.95)

(21) International Application Number: PCT/US95/02440

(22) International Filing Date: 27 February 1995 (27.02.95)

(30) Priority Data:

08/203,909

28 February 1994 (28.02.94)

US

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(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TT, UA, UG, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ, UG).

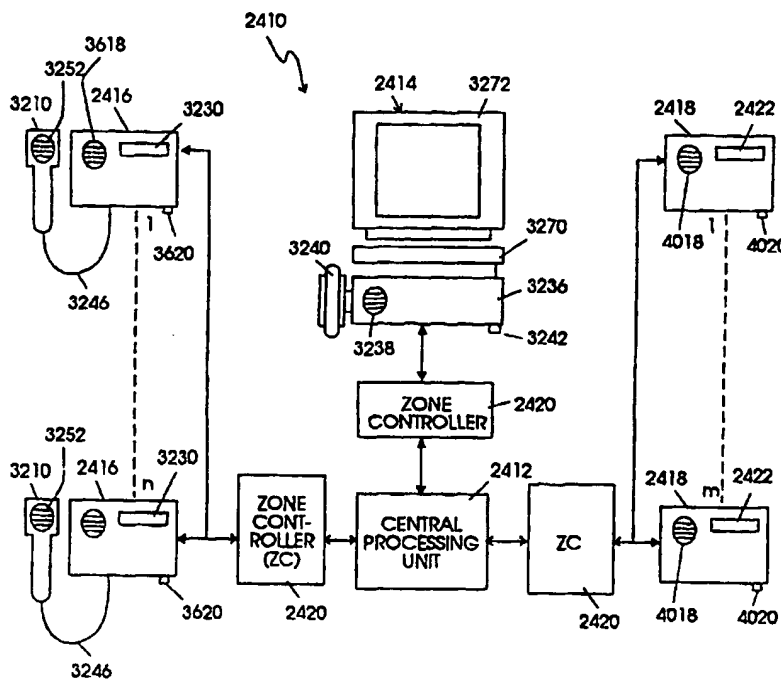
## Published

Without international search report and to be republished upon receipt of that report.

(54) Title: PATIENT CARE AND COMMUNICATION SYSTEM

## (57) Abstract

The present invention relates to a patient care and communication system which utilizes a central processing system and a plurality of remote stations electrically connected to the central processing system to facilitate visual and data communications. Each remote station includes telephone circuitry which is connected to a private branch exchange for telephones communications between stations. In addition, the private branch exchange is connected to a telephone exchange and a plurality of telephones for facilitating telephone communication therebetween. The central processing system facilitates the visual and data communications between the plurality of remote stations, and includes a system for determining which of the plurality of remote stations are transmitting the visual and data communications and which of the plurality of remote stations are to receive the visual and data communications. The central processing system also includes a system which establishes a communication link between the transmitting stations and the receiving stations. The remote stations include a processing system which also facilitates the visual, data and telephone communications and a display for displaying the visual communications. The present invention also includes a staff and/or patient locator system, in which each remote station includes an infrared receiver that receives infrared transmissions from a portable transmitter worn by a staff member or patient. The infrared transmissions include identity information associated with the person wearing the transmitter. The identity information is then transferred to the central processing system which determines the identity and location of each person wearing a portable transmitter.



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PATIENT CARE AND COMMUNICATION SYSTEMCROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of  
5 Application Serial No. 08/087,394, filed July 2, 1993, and  
is a continuation-in-part of Application Serial No.  
08/033,287, filed March 16, 1993, which is a continuation-  
in-part of copending Application Serial No. 07/924,101,  
filed August 3, 1992, which is a continuation-in-part of  
10 Application Serial No. 07/559,196 filed on July 27, 1990.

BACKGROUND OF THE INVENTION1. Field of the Invention

The present invention relates to a patient care  
15 and communication system which incorporates telephone  
communication therein. The system utilizes a PBX to provide  
staff-to-staff, staff-to-patient and/or external telephone  
communications. The system is also capable of performing  
tasks such as monitoring medical equipment in patient rooms  
20 and maintaining patient medical data; facilitating staff-to-  
staff or staff-to-patient visual and data communications;  
and tracking the location of staff members or patients to  
provide maximum patient care. More detailed descriptions of  
the staff-patient communications and the monitoring of the  
25 medical equipment is provided in Application Serial No.  
08/033,287, filed March 16, 1993 which is incorporated  
herein by reference. A more detailed description of the  
system for tracking the location of personnel is provided in  
Application Serial No. 08/087,394, filed July 2, 1993 and  
30 Application Serial No. 07/924,101, filed August 3, 1992 both  
of which are incorporated herein by reference.

1    2.    Description of the Related Art

          In hospital or other health care environments, the nursing staff as well as other staff members are required to maintain and update patient information, provide patient  
5    care, and assist physicians in the treatment of patients. Often, these tasks have to be performed even though there are personnel shortages. Further, as medical technology continues to develop to provide treatment for a greater  
10    number of medical conditions, the volume of information that is maintained for each patient continues to grow rapidly. As a result, stress on the nursing staff has increased and information overload is fast approaching.

          To more fully understand the above problem relating to health care, consider the types of data which  
15    are maintained for an individual patient. Typically, the staff members need to know the patient's name and address as well as any special dietary, environmental or physical space requirements of the patient. The attending physician or nursing staff may want to know the patient's condition,  
20    medical history and recent vital sign data. If the patient has had any diagnostic tests such as x-rays or ultrasound images made at the hospital, or at any other hospital, the attending physician may want to compare these test results with the results of newer tests to see how the patient's  
25    condition has progressed. In addition, if any medication has been prescribed, the physician or nursing staff may want to know the identity of the medication, when the last dose was taken and how the patient has complied with the dosage schedule.

30           Current systems utilized to manage such information includes the manual writing and processing of the information. Electronic systems utilized to process and store the information involve multiple computers, each  
35

1 configured to process portions of the vast amount of  
information. To obtain all the information in one place the  
information stored in each computer system must be manually  
combined. Furthermore, such electronic systems do not  
5 provide visual displays of text at stations provided in the  
patient's room, at the nurse control station or at stations  
provided in areas of the health care facility frequently  
occupied by the health care personnel.

In addition to processing the above information,  
10 the nursing staff attending to a number of patient's rooms  
may want to have some indication of each patient's condition  
at nursing stations which are far removed from the patient's  
bed. For example, if the patient has been admitted for a  
heart condition, it would be helpful if any recent vital  
15 signs that may indicate the onset of a heart attack could be  
displayed at the nurses station when the patient presses a  
call button.

One such system described in U.S. Patent No.  
4,835,372 to Gombrich et al. relates to a patient  
20 identification system for relating items with patients and  
for ensuring that an identified item corresponds to an  
identified patient. The system includes a computer system  
interconnected to a plurality of remote terminals by  
conventional telephone wiring. A RF modem provides for  
25 transmission and reception of RF signals to and from a bar  
code reading device, and the RF modem provides for  
transmission and reception of signals via existing telephone  
wire to and from the computer system using data over voice  
technology.

30 Another problem faced by care givers and by  
hospital administrators is determining the location of key  
personnel and equipment. In an emergency or during periods  
of personnel shortages, the ability to quickly locate an

1 attending physician or other staff member to provide maximum  
patient care is desirable. Moreover, when special equipment  
is required to treat an emergency condition or when a ward  
of a hospital is experiencing personnel shortages, it is  
5 desirable that the equipment be quickly located to reduce  
the time spent to locate the equipment.

One type of system utilized to locate personnel  
within a hospital or other health care facility relies on  
audio paging systems, sign-in and sign-out sheets and  
10 broadcast paging systems. In a given situation, the audio  
paging system would be tried first. This system may not be  
effective if the person to be located is in an area where  
the paging system is not functioning properly or has been  
turned down, or if the person has left the hospital. After  
15 an unsuccessful audio page, the sign-in and sign-out sheets  
may be checked. If, however, the person to be located  
forgot to use the sign-in sheet or sign-out sheet, critical  
time may be lost in a second attempt to use the audio paging  
system. In addition, a search of the sign-in and sign-out  
20 sheets may require more time than is available in an  
emergency situation.

When the person to be located is outside of the  
hospital, broadcast paging systems are often the best way to  
convey an important message. These systems require the  
25 individual trying to locate the person to call the paging  
service, leave a message, wait for the paging service to  
send the message to the individual's pocket pager and then  
wait for the person being paged to call the paging service,  
receive the message and respond.

30 Another type of currently used locator system  
utilizes either radio frequency signals or infra-red signals  
to communicate the position of a mobile individual or object  
to a network of stationary transceivers. One such system,

1 the InfraCom locating and signaling system available from  
United Identification Systems Corp. is designed for use in a  
hospital environment. Using this system, a network of  
infra-red transceivers located throughout a hospital can  
5 both transmit data to and receive data from a portable badge  
worn by hospital personnel or attached to the equipment to  
be located. This badge transmits a programmed  
identification signal to the network allowing the position  
of the badge to be indicated on a display of the floor plan  
10 of the hospital.

Another exemplary system, the TELOC PLUS personnel  
locator system available from Teloc, Inc., also uses two-way  
infra-red signaling to communicate the position of a  
portable badge in a stationary transceiver. In addition,  
15 the Teloc system may be coupled to a private branch exchange  
(PBX) to allow telephone calls from an individual to be  
routed to the telephone that is closest to the badge or to  
direct an intercom message to that telephone, thus providing  
an alternative to an audio paging system. Each of these  
20 systems is limited in the type of information that may be  
conveyed between the stationary transceiver network and the  
transceiver on the badge. In the described systems, only  
identification information providing an indication that  
switches, which are located on the badge have been  
25 activated, may be transmitted from the badge. Furthermore,  
if the transceiver on the badge fails or is damaged, a blank  
badge must be programmed to take its place. This program  
operation may be time consuming, leaving the individual or  
the piece of equipment invisible to the locating system for  
30 that period of time.

Therefore, a need exists for a patient care and  
communication system which integrates a staff locating  
system with a system which facilitates visual and data

1 communications between staff members and patients and which  
maintains patient data. A need also exists for a patient  
care and communication system which utilizes a private-  
branch exchange to provide staff-to-staff, staff-to-patient  
5 and/or external communications. The present invention  
provides a patient care and communication system which  
provides communications through a PBX and which is capable  
of performing tasks such as monitoring medical equipment in  
patient rooms and maintaining patient medical data,  
10 facilitating voice, visual and data communications between  
staff members and the patients, as well as a system for  
tracking staff members to provide maximum patient care.

#### SUMMARY OF THE INVENTION

15 The present invention relates to a patient care  
and communication system which includes a central station  
having means for facilitating visual and data communications  
relating to health care and a plurality of remote stations  
connected to the central station. The remote stations  
20 include processing means for facilitating the visual and  
data communications and display means for displaying the  
visual communications.

The central station includes means for determining  
which of the plurality of remote stations are transmitting  
25 the visual and data communications and which of the  
plurality of remote stations are to receive the visual and  
data communications. In addition, the central station  
includes means for establishing a communication link between  
the transmitting stations and the receiving stations, and  
30 each of the plurality of remote stations includes telephone  
circuitry for connection to a private-branch exchange for  
telephone communications therebetween.



1            Preferably, the plurality of remote stations  
includes control stations, patient stations and staff  
stations and the central station includes means for  
directing the visual and data signals transmitted to the  
5 control stations to a predetermined number of patient  
stations and a predetermined number of staff stations.

          The present invention also provides a patient care  
and communication system where the plurality of remote  
stations are configured and adapted for association in a  
10 group network such that predefined visual and data signal  
communications are transmitted to each station in the group.  
Zone controller means are provided to interface the central  
processing means to the transmitting and receiving stations.

          In the preferred embodiment, the central station  
15 also includes means for controlling the private-branch  
exchange to establish audio communication between a  
predetermined number of control stations, a predetermined  
number of the patient stations and a predetermined number of  
the staff stations.

20            The patient stations of the present invention  
include patient control means which is connected thereto and  
provide a remote communication link between the patient and  
staff members or the patient and outside callers. The  
patient control means has a keypad, a speaker and a  
25 microphone for telephone communications to other stations or  
for external telephone communications. It should be noted  
that external communications includes telephone  
communications from within the hospital environment to  
locations outside the hospital environment, generally via  
30 public telephone lines.

          The system of the present invention also relates  
to a method of providing patient care and communication  
between patient rooms and nurse stations in a health care

1 facility. The method includes the steps of connecting a  
plurality of remote stations to a central station so as to  
facilitate visual and data communications therebetween, and  
connecting each remote station and the central station to a  
5 private-branch exchange for audio communications between the  
remote stations. At least one of said plurality of remote  
stations is positioned in each patient room located within  
the health care facility, positioning at least one of said  
plurality of remote stations in each nurse station of said  
10 health care facility, attending the remote station in each  
nurse station to receive the visual and data signals from  
said central station and the audio signals from the PBX and  
responding to the audio, visual and data signals.

15 BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments of the invention are  
described hereinbelow with reference to the drawings  
wherein:

Fig. 1 is an illustration of the components of one  
20 embodiment of the patient care and communication system  
configuration of the present invention;

Fig. 2 is a functional block diagram of an  
alternative embodiment of a system configuration of the  
present invention;

25 Fig. 3 is a functional block diagram of an another  
alternative embodiment of a system configuration of the  
present invention, illustrating grouping arrangements for  
the stations;

Fig. 4 is a functional block diagram of an another  
30 alternative embodiment of a system configuration of the  
present invention;

Fig. 5 is a circuit block diagram for the central  
processing unit illustrated in Fig. 1;

1           Fig. 6 is flow-chart diagram for the central  
processing unit illustrated in Fig. 1;

          Fig. 7 is a block diagram for the fail safe  
feature associated with the system of the present invention;

5           Fig. 8 is a flow-chart diagram of the fail safe  
feature illustrated in Fig. 7;

          Fig. 9 is a functional block diagram of a system  
configuration similar to Fig. 1, illustrating a patient  
station having peripheral equipment connected thereto;

10          Fig. 10 is a block diagram for the nurse control  
station illustrated in Fig. 1;

          Fig. 11 is a circuit block diagram for the audio  
circuitry of the keyboard of the nurse control station  
illustrated in Fig. 1.

15          Figs. 12 and 13 are circuit block diagrams for the  
internal circuitry for the patient stations illustrated in  
Fig. 1;

          Figs. 14a and 14b illustrate an exemplary flow-  
chart diagram of an operation of the patient station of Fig.  
20 1;

          Fig. 15 is a flow-chart diagram associated with  
the internal circuitry for the patient stations illustrated  
in Fig. 1;

          Figs. 16 and 17 are circuit block diagrams for the  
25 internal circuitry for the staff stations illustrated in  
Fig. 1;

          Figs. 18, 19 and 20 are tables which illustrate  
various call indications and associated tones generated by  
the stations in response to a particular call condition;

30          Fig. 21 is flow-chart diagram for the central  
processing unit illustrated in Fig. 12; and

          Fig. 22 is a circuit diagram for the patient  
control unit illustrated in Fig. 10 and showing self-test

1    circuitry for performing automatic continuity tests of  
interconnecting wires;

Fig. 23 is an illustration of the components of an  
alternative embodiment of the patient care and communication  
5    system of the present invention;

Fig. 24 is a functional block diagram of the  
alternative embodiment of the patient care and communication  
system configuration of Fig. 23, illustrating a private-  
branch exchange connected to the stations for telephone  
10    communications;

Fig. 25 is a circuit block diagrams for an  
alternative embodiment of the internal circuitry for the  
patient stations illustrated in Fig. 23;

Fig. 26 illustrates the data frames for  
15    communication between the stations and the private-branch  
exchange;

Fig. 27 illustrates the data frames for  
communication from the stations to the private-branch  
exchange in an expanded form;

20    Fig. 28 illustrates the data frames for  
communication from the private-branch exchange to the  
stations in an expanded form;

Fig. 29 is a circuit block diagram for an  
alternative embodiment of the internal circuitry for the  
25    patient control units illustrated in Fig. 23;

Fig. 30 is a circuit block diagram for an  
alternative embodiment of the internal circuitry for the  
nurse control stations illustrated in Fig. 23;

Fig. 31 is an illustration of the components of  
30    another alternative embodiment of the patient care and  
communication system configuration of the present invention;

1           Fig 32 illustrates exemplary input and output  
waveforms for the waveshaping and conditioning circuitry of  
Fig. 25;

5           Fig. 33 is a block diagram of the components of an  
exemplary portable transmitter according to the present  
invention;

          Figs. 34-36 illustrate a side elevational view,  
top plan view and a bottom plan view, respectively, of a  
housing for the transmitter components of Fig. 33;

10          Figs. 37 and 38 illustrate front and rear views,  
respectively, of a personnel card used with the transmitter  
housing and components of Fig. 35;

          Fig. 39 is an exemplary configuration for a  
patient room within a health care facility;

15          Fig. 40 is a circuit block diagram of an infrared  
receiver and environmental facilities within the patient  
room of Fig. 39, which are connected to a controller;

20          Fig. 41 is an alternative configuration for a  
patient room within a health care facility, illustrating the  
utilization of a wireless system for controlling  
environmental facilities in the room; and

          Fig. 42 is a block diagram of an alternative  
portable transmitter embodiment according to the present  
invention.

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#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

          Generally, the patient care and communication  
system of the present invention includes a communication  
network that provides routine and emergency signaling to  
30 health care facility staff members and provides high  
fidelity voice communication and data transmission between

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1 staff members in the health care facility and/or between  
patients and the staff members.

The exemplary embodiments of the automatic staff  
locator system of the patient care and communication system  
5 of the present invention described below, use a memory card  
as a personal database. As used herein, a memory card is a  
device approximately the same size and shape as an ordinary  
credit card which includes a non-volatile programmable  
memory. In the card used in the embodiments described  
10 below, two types of memory are used: an electronically  
erasable read only memory (EEROM) located internal to the  
card and a magnetic stripe located on the surface of the  
card. It is contemplated, however, that other forms of  
internal memory, such as a ferro-electric RAM or a CMOS  
15 memory with an integral battery, may be used. It is also  
contemplated that the functions described below may be  
implemented with other types of external memory, such as  
laser card technologies which either augment or replace the  
card memory. A more detailed description of the staff  
20 locator system and its operation is described in commonly  
assigned U.S. Application Serial No. 08/033,287, filed on  
March 16, 1993 and which is incorporated herein by  
reference.

#### 25 SYSTEM CONFIGURATIONS AND COMMUNICATIONS

Fig. 1 is an illustration of the major components  
of the patient care and communication system according to  
the present invention, which includes central processor unit  
(CPU) 2412, nurse control stations 2414, patient stations  
30 2416, staff stations 2418 and zone controllers 2420.  
Generally, the nurse control stations 2414 are installed at

1 nurse stations located in various areas of the hospital or  
health care facility and provide a communication link to  
patients in their rooms. The patient stations 2416 are  
installed in patient rooms and can be configured to  
5 correspond to one patient or to multiple patients. The  
patient stations 2416 include patient station display 3230,  
speaker 3618, microphone 3620 and patient control unit 3210,  
all of which will be described in more detail below.

The staff stations 2418 are preferably installed  
10 in locations frequently occupied by other staff members in  
the hospital, such as staff locker rooms. Staff stations  
2418 include staff station display 2422, speaker 4018 and  
microphone 4020, all of which will also be described in more  
detail below. The zone controllers 2420 include shared-RAM  
15 (S-RAM) memory 2512 (shown in Fig. 2) which is utilized as a  
buffer memory for data received from either CPU 2412 or from  
any of the above noted stations, hence the term shared-RAM.

As will be described in more detail below, the  
various types of stations which are positioned at different  
20 locations within the hospital interact with the aid of the  
CPU 2412 to perform numerous operations to reduce the  
information overload currently plaguing hospital staff  
members. Examples of the operations involving CPU 2412  
include a call priority operation which prioritizes incoming  
25 calls (or messages) to nurse control station 2414 based upon  
the type of message received, so that staff members respond  
to the highest priority calls first. For example, if the  
incoming message relates to a fault in a smoke alarm secured  
in the patient's room, that message will be given the  
30 highest priority. Another operational example is a nurse  
follow operation which allows staff members to selectively

1 route incoming calls directed to a nurse control station, to  
selected patient stations and/or staff stations so that when  
the staff members attending the nurse control station are  
required to leave the area, incoming calls to that station  
5 can be routed to locations where appropriate staff members  
can respond to the call. Another operational example is a  
voice paging operation which allows staff members to  
communicate with selected patient stations 2416 and/or staff  
stations 2418 from the nurse control station 2414. The  
10 interaction between the stations when performing these  
exemplary operations or tasks, as well as other operations,  
is conducted via a communication link which will be  
described in more detail below.

Fig. 3 illustrates the major components of system  
15 2410 arranged in groups. As shown, CPU 2412 of the system  
of the present invention is configured, dimensioned and  
adapted to interface through zone controller systems 2413  
with a predetermined number of station groups of patient  
stations 2416, staff stations 2418, and/or any combination  
20 thereof (e.g., the number of groups ranging between 1 and x,  
where "x" is preferably 8). Each station group includes  
between 1 and "n" stations, where "n" is preferably 35, and  
a predetermined number of station groups can be assigned to  
between 1 and "m" nurse control stations 2414, where "m" is  
25 preferably 8. For example, if a ward in a hospital has one  
hundred patient rooms (numbered from 100 to 200) which are  
single occupancy rooms, a staff locker room (Room 201) and a  
staff kitchen (Room 202), one patient station 2416 would be  
installed in each patient room and one staff station 2418  
30 would be installed in the staff locker room and the staff



1 kitchen. An exemplary array of station groupings (or the  
call assignment configuration) is shown in Table I below:

Table I

	RM1	RM2	RM3.....RM32	RM33	RM34	RM35
GROUP 1	100	101	102.....132	133	201	202
GROUP 2	120	121	122.....152	153	201	202
GROUP 8	154	155	156.....186	187	201	202

As shown in this exemplary call assignment configuration,  
rooms 100 through 133, 201 and 202 are assigned to station  
group 1. Rooms 120 through 153, 201 and 202 are assigned to  
station group 2 and rooms 154 through 187, 201 and 202 are  
assigned to station group 8. The station groupings can  
overlap in room coverage, thus, as illustrated in table I  
above, station groups 1 and 2 both include rooms 120 through  
133.

In addition to the station groupings, the system  
of the present invention is configured so that each station  
group is assigned to a predetermined number of nurse control  
stations 2414. Table II below, illustrates an exemplary  
call assignment configuration for station groupings and  
their assignment to the nurse control stations 2414:

Table II

	Group 1	Group 2	.....	Group 8
NCS1	YES	YES	.....	YES
NCS2	YES	NO	.....	NO
NCS8	NO	YES	.....	NO

In this exemplary configuration, communication transmitted  
by any of the stations assigned to station group one (rooms  
100-133, 201 and 202) will be directed to nurse control

1 station one (NCS1) and to NCS2 so that staff members  
attending either nurse control station 2414 can respond to  
the call. Communications transmitted by any of the stations  
assigned to station group two (rooms 120-153, 201 and 202)  
5 will be directed to NCS1 and NCS8 so that staff members  
attending either nurse control station 2414 can respond to  
the call. Communications transmitted by any of the stations  
assigned to station group eight (rooms 154-187, 201 and 202)  
will be directed to NCS1 so that staff members attending  
10 NCS1 can respond to the call.

In the preferred embodiment, the patient care and  
communication system of the present invention can include  
four call assignment configurations. To illustrate, the  
call assignment configurations can be utilized to  
15 automatically (or manually) assign stations (2416 or 2418)  
to station groups and station groups to nurse control  
stations 2414 for day operation, for evening operation, for  
weekend operation and/or for holiday operation.

Referring now to Fig. 4 which illustrates an  
20 alternative system configuration in which, central  
processing unit 2412 is connected to external communication  
equipment such as broadcast paging system 2720, external  
computer 2722, printer 2724, and/or staff locator system  
2428. Broadcast paging system 2720 may be utilized by the  
25 system of the present invention to locate staff members or  
other personnel who are not within the hospital or other  
health care facility. The broadcast paging system may be  
any known type capable of interfacing with a computer.  
Preferably, broadcast paging system 2720 and CPU 2412  
30 communicate via serial communication ports connected to each  
device. Staff locator system 2428 may be provided to locate

1 staff members anywhere in the hospital or other health care  
facility as described in U.S. Application Serial No.  
07/924,101, filed August 3, 1992, which is incorporated  
herein by reference. In addition to locating staff members,  
5 staff locator system 2428 may be utilized to track or locate  
patients in the hospital. To utilize the staff locator  
system to locate patients, each patient is provided with an  
identification badge or bracelet which includes the  
components as disclosed for identification badge worn by  
10 staff members and described above. The identification badge  
or bracelet continually transmits the identification signal  
of the patient and the central computer system continually  
monitors the identification signal to update the location of  
the bracelet and the patient. The location information of  
15 the staff member or patient is transferred to CPU 2412 via  
data link 2726 (shown in Fig. 4) which may be any known type  
of communication link utilized to facilitate communication  
between computer systems. External computer 2722 interfaces  
to CPU 2412 and performs computing functions including  
20 extracting or inputting data stored or otherwise processed  
within CPU 2412. Printer 2724 may be utilized to extract  
hard copies of data stored or otherwise processed within CPU  
2412 including problem reports generated by the system, as  
will be described in more detail below.

25 Fig. 2 illustrates a functional block diagram of  
an alternative system configuration, which includes main  
hospital computer 2530 configured to interface with CPU 2412  
to provide staff members with additional patient  
information, or to transfer from CPU 2412 to the main  
30 hospital computer patient information which may be utilized  
for billing purposes. For example, information pertaining

1 to the types and quantities of prescription or intravenous  
drugs taken by the patient and the types of treatments  
received by the patient (e.g., X-rays or CT-scans), as well  
as the physician time spent with the patient, may be  
5 transferred to the main hospital computer to provide the  
hospital with more accurate billing information.  
Preferably, main hospital computer 2530 is interfaced with  
CPU 2412 via hospital personal computer 2540, system  
personal computer 2550, RS-232/RS-484 converter 2520 and  
10 zone controller 2560. In this configuration, the integrity  
of the main hospital computer is maintained and the serial  
conversion from RS-232 protocol to RS-484 protocol is  
accomplished.

Fig. 5 illustrates the hardware components of  
15 central processing unit (CPU) 2412. The CPU 2412 includes  
microprocessor 2810, three Mbytes of memory 2820 (2 Mbytes  
of flash ROM and 1 Mbyte of RAM) having stored programs  
(e.g., operating system and application programs), and  
communication interface 2830. Preferably, microprocessor  
20 2810 is an MC68000 16-bit microprocessor manufactured by  
Motorola Inc. In addition to the above circuits, CPU 2412  
includes watchdog circuit 2840 which receives a one shot  
trigger from microprocessor 2810, at a predetermined time  
interval, preferably 300 msec., to ensure that the  
25 microprocessor is functioning. If, however, microprocessor  
2810 fails to timely trigger watchdog circuit 2840, then the  
watchdog circuit will initiate an automatic reset of the  
microprocessor, thus preventing the microprocessor from  
locking-up for extended periods of time.

30 Communication interface 2830 and communication  
ports 2850 are provided to facilitate communication between

1 CPU 2412 and zone controllers 2420 and between CPU 2412 and  
the external communication equipment. As noted above, the  
preferred communication protocol includes the RS-485 serial  
communication protocol. Accordingly, communication  
5 interface 2830 is configured to accommodate RS-485  
communication utilizing RS-485 drivers/receivers which are  
known in the art.

An exemplary operational flow of CPU 2412 is shown  
in Fig. 6. Initially, the CPU is in a listen mode. In the  
10 listen mode the CPU continuously polls or otherwise  
interrogates the different components attached thereto. For  
example, as shown in Fig. 6, the CPU will periodically poll  
each shared-RAM (S-RAM) 2512 (shown in Fig. 2) of each zone  
controller (step 2910) in a manner described hereinbelow.  
15 If the S-RAM does not have a message frame received from a  
station within the zone controller grouping, CPU 2412  
returns and polls the next zone controller (step 2920).  
Preferably, as will be described in more detail below data  
transmitted between the CPU 2412 and the zone controller  
20 2420 or between the zone controller 2420 and the stations  
(either 2414, 2416 or 2418) are in the form of message  
frames which include station identity information as well as  
the message data relating to a particular function.

If, however, the S-RAM does have a message frame  
25 stored therein, CPU 2412 will retrieve the message frame  
(step 2930) and analyze the received message frame by  
determining what patient station, staff station or nurse  
control station the message frame was received from and if  
the frame was received from a patient station, by organizing  
30 or obtaining any patient information associated with that  
particular patient station (step 2940). The DATA field

## 20

1 within the INFORMATION field of the received message frame  
is then interpreted by the CPU, which determines whether a  
response to the associated patient station, staff station or  
nurse control station message frame is necessary (step  
5 2950). If a response is not required, CPU 2412 returns to  
poll the next zone controller.

However, if a response is due, the CPU then starts  
the task associated with the information included in the  
message frame (step 2960). Upon completion of the task, CPU  
10 2412 returns to the listen mode and begins polling the next  
zone controller connected thereto as described above.

The components of zone controller 2420 include a  
microcontroller, memory having stored programs (e.g., system  
or application programs) and a communication interface  
15 connected to communication ports. The connection of the  
zone controller 2420 components is the same as equivalent  
components of CPU 2412, as shown in Fig. 5. The zone  
controller 2420 also includes the shared-RAM (S-RAM) 2512,  
shown in Fig. 2, which is connected to the microcontroller.  
20 Preferably, the microcontroller is the 64180  
microcontroller, manufactured by Motorola and the S-RAM  
includes 2 kilobytes of memory.

A communication interface and communication ports  
are provided to facilitate communication between zone  
25 controller 2420, CPU 2412 and slave devices, such as patient  
station 2416, staff station 2418 and/or nurse control  
station 2414. The communication protocol may be any known  
serial communication protocol, such as RS-232 or RS-485.  
The RS-485 protocol is preferred in the embodiment according  
30 to the present invention. Accordingly, the communication  
interface is configured to accommodate RS-485 communication

1 utilizing RS-485 drivers/receivers which are known in the  
art. Each zone controller 2420 also includes a watchdog  
circuit which operates similarly to the watchdog circuit in  
CPU 2412. Thus, the watchdog circuit prevents the  
5 microcontroller from locking-up if the watchdog circuit is  
not polled at the predetermined time interval, preferably  
300 msec., by the microcontroller.

The communication link between the zone  
controllers and stations or between the stations and  
10 peripheral equipment connected to the station is in a  
master-slave relationship. In the communication link  
between the zone controllers 2420 and the stations, the zone  
controllers are the master stations and the nurse control  
stations, patient stations or staff stations are the slave  
15 stations. Whereas, in the communication link between the  
stations and the peripheral equipment, the stations (e.g.,  
the patient stations) are the master stations and the  
peripheral equipment is the slave. The master station is in  
control of the data link and transmits command frames to the  
20 slave stations. The master station maintains separate  
sessions (i.e., communication links) with each slave station  
attached to the link. To illustrate and again referring to  
Fig. 2, if zone controller 2420 is connected to a group of  
patient stations (1 to n) and/or connected to a group of  
25 staff stations (1 to m), the zone controller (master) will  
periodically poll each patient station (slave) to retrieve  
message frames. The slave station responds to the commands  
from the master station and can send one message to the  
master station per poll from the master station.

30 The master station may communicate with the slave  
stations in one of two logical states. One state is the

1     INITIALIZATION state which is used to initialize the  
master/slave station (e.g., identify for each communication  
link which device connected thereto is the master and which  
is the slave). A second state is the INFORMATION TRANSFER  
5     state which permits the master and slave stations to  
transmit and receive control or application information  
transmitted across the data link between the master station  
and the slave stations in the form of message frames or  
blocks of data.

10             In the preferred embodiment, the message frames  
may be one of three types. The first type of message frame  
is the INFORMATION FORMAT frame (I-frame) which is used to  
transmit application information (e.g., message information  
15     associated with a particular function or station status  
data) between the master and slave stations. The I-frame  
may also acknowledge receipt of a frame from a transmitting  
station. The second type of message frame is the  
SUPERVISORY FORMAT frame (S-frame) which performs control  
functions, such as acknowledging the receipt of a poll from  
20     the master station or requesting the temporary suspension of  
the transmission of I-frames. The third type of message  
frame is the UNNUMBERED FORMAT frame (U-frame) which is also  
used for control purposes, such as performing data link  
initialization or tests.

25             As noted, the data (or information) transmitted  
between master and slave stations is preferably configured  
in the form of a message frame. The preferred message frame  
includes five fields, similar to the frame shown below:

30                     ADDRESS/LENGTH/CONTROL/INFORMATION/FCS

35



1 Where, the ADDRESS field is one byte in length and  
identifies the patient station involved in the particular  
frame transaction (each station has a unique address which  
allows the CPU and zone controller to identify which station  
5 sent the frame); the LENGTH field is one byte in length and  
contains the size of the frame, in bytes, excluding the  
address and length fields; the CONTROL field includes the  
command and response information used to maintain data-flow  
accountability of the communication link between the zone  
10 controller (master) and the patient station (slave); and the  
INFORMATION field retains a predetermined number of bytes of  
data, preferably between 1 and 145 bytes, relating to the  
application data, such as, the data associated with the  
activation of the nurse call button (hereinafter "the nurse  
15 call data"). The frame-check-sequence (FCS) field,  
typically one byte in length, is used to check for  
transmission errors between the master and slave stations or  
devices.

The system of the present invention may transmit a  
20 predetermined number of message frames, preferably between 1  
and 8 frames, before an acknowledgement or response to a  
transmitted frame is received. As a result, the CONTROL  
field is utilized to maintain data-flow accountability of  
the communication link, as noted above.

25

30

35

1 Shown in table III below is the CONTROL field bit  
encoding for the master and slave stations.

Table III

	CONTROL field bit encoding (master station):
	I-frame format:
5	:7:6:5:4:3:2:1:0:
	: x x : x x : 0
	: : : : : : : : -> Normally set to binary 0
	: : : : : : : :
	: : : : : : : -> N(S)
	: : : : : : : :
	: : : : : : : -> N(R)
	: : : : : : : :
	: : : : : : : -> P
10	CONTROL field bit encoding (slave station):
	I-frame format:
	:7:6:5:4:3:2:1:0:
	: x x : x x : 0
	: : : : : : : : -> Normally set to binary 0
	: : : : : : : :
	: : : : : : : -> N(S)
	: : : : : : : :
	: : : : : : : -> N(R)
	: : : : : : : :
15	: : : : : : : -> P

The send sequence number N(S) (bits 1, 2 and 3) indicates the sequence number associated with a transmitted frame. Basically, the sequence number is a message counter which counts the number of message frames sent to a receiving station. The receive sequence number N(R) (bits 1, 2 and 3) indicates the next sequence number that is expected at the receiving station. The receive sequence number may also serve as an acknowledgement of the previous frame. In addition, the transmitting station maintains a send state variable V(S) which is the sequence number of the next message frame to be transmitted, and the receiving station maintains a receive state variable V(R), which contains the number that is expected to be in the sequence number of the next frame. The send state variable is

1 incremented with each message frame transmitted and placed  
in the send sequence number N(s) field in the frame.

Upon receiving a frame, a receiving station checks  
for a transmission error by comparing the send sequence  
5 number with the receive state variable. If the frame is  
acceptable (i.e., the send sequence number and the receive  
state variable are equal), the receiving station increments  
the receive state variable V(R) and interpolates the  
variable into the receive sequence number field N(R) in the  
10 next outbound message frame. If, on the other hand, the  
send state variable V(S) does not match the receive sequence  
number N(R) in the message frame, the receiving station  
decrements the send state variable V(S) and retransmits the  
last message frame when the next frame has to be  
15 transmitted.

To establish an interactive communication link  
between stations, the master station uses the poll bit (P)  
to solicit a status response (e.g., an S-frame) or an I-  
frame from a slave station. Generally, the slave station  
20 does not transmit a frame to a master station until a  
message frame with an active poll bit (i.e., P is set to  
logic 1) is received from the master frame. In the  
preferred embodiment, the polling rate of the master station  
is aperiodic or not fixed. The polling rate is dependent  
25 upon a number of factors such as the baud rate and the type  
of message frame being sent by the slave station. For  
example, if the baud rate is 9600 and if all the slave  
stations respond to a poll by the master station with an S-  
frame, the polling rate is approximately 20 msec. However,  
30 if a slave station responds with an I-frame which includes  
64 bytes of display data the rate (or time) before the

1 master station will poll the next slave station is  
approximately 64 msec. Generally, at 9600 baud, one byte of  
data is transferred in one millisecond.

The slave station responds to an active poll bit  
5 with an I-frame or S-frame format message frame. In the  
preferred embodiment, the slave station has 15 msec. to  
start transmitting the responding message frame and 150  
msec. to complete transmission of the frame which is  
identified by activating the Final bit (F) (i.e., F is set  
10 to a logic 1).

If the slave station fails to successfully respond  
to the polling frame of the master station with either an S-  
frame or I-frame, for a predetermined number of polls,  
preferably 10, that particular station will be marked as  
15 disconnected and will be polled at slower rate (preferably,  
about every 10 sec.) until the master station receives at  
least one message frame from that particular slave station.  
When a station or other equipment connected to the system of  
the present invention are determined to be disconnected, the  
20 identity of the station or other equipment and the room  
location of the equipment are stored in a problem report  
which can be printed on hard or soft copy via printer 2724  
and/or external computer 2722, shown in Fig. 4.  
Alternatively, the problem report can be displayed on nurse  
25 control station display 3272 shown in Fig. 32 upon the  
proper keying of direct select keys 3374 of nurse control  
station display 3272 pursuant to menu prompts.

30

35

1 Referring now to Table IV below, the CONTROL field  
encoding for the commands and responses used by an S-frame  
are shown:

Table IV

5	CONTROL field bit encoding (master station):
	S-frame format:
	:7:6:5:4:3:2:1:0:
	: x x : : : 0 1
	: : : : : : : -> Normally set to binary 1
	: : : : : : :
	: : : : : : -> Commands:
	: : : : : : -> Binary 0 - Receive Ready (RR)
	: : : : : : -> Binary 1 - Receive Not Ready (RNR)
10	: : : :
	: : : : -> N(R)
	:
	: -> Poll bit (P)
	CONTROL field bit encoding (slave station):
	S-format:
	:7:6:5:4:3:2:1:0:
	: : : : : 0 1
15	: : : : : : -> Normally set to binary 1
	: : : : : : :
	: : : : : : -> Commands:
	: : : : : : -> Binary 0 - Receive Ready (RR)
	: : : : : : -> Binary 1 - Receive Not Ready (RNR)
	: : : :
	: : : : -> N(R)
	:
	: -> Final bit (F)

20 The receive ready (RR) command is used by either  
the master or the slave station to indicate that it is ready  
to receive an I-frame and/or acknowledge previously received  
frames by using the receive sequence number. If a station  
had previously indicated that it was busy by using the  
25 receive not ready (RNR) command, the station then uses the  
RR command to indicate that it is now free to receive data  
(e.g., an I-frame).

As noted, receive not ready (RNR) is used by a  
receiving station to indicate a busy condition in response  
30 to polling by a master station. This notifies the

1 transmitting station that the receiving station is unable to  
accept I-frames. The RNR command may also be utilized to  
acknowledge a previously transmitted frame by using the  
receive sequence number.

5 The commands and responses used by a U-frame are  
shown below in Table V:

Table V

	CONTROL field encoding (master station)
	U-frame format:
	:7:6:5:4:3:2:1:0:
	: : : : : 1 1
10	: : : : : :-> Normally set to binary 3
	: : : : : :
	: : : : : :-> Commands:
	: : : : : :-> 0 - Set Init. Mode (SIM)
	: : : : : :-> 1 - Reset Init. Mode (RIM)
	: : : : : :-> 2 - Test Message (TM)
	: : : : : :-> 3 - Loop Back (LB)
	: : : : : :-> 4 - Broadcast (BC)
	:
15	: : : : : :-> Poll bit (P)
	CONTROL field encoding (slave station)
	U-format:
	:7:6:5:4:3:2:1:0:
	1 : : : : : 1 1
	: : : : : :-> Normally set to binary 3
	: : : : : :
	: : : : : :-> Commands:
20	: : : : : :-> 0 - Set Init. Mode (SIM)
	: : : : : :-> 1 - Reset Init. Mode (RIM)
	: : : : : :-> 2 - Test Message (TM)
	: : : : : :-> 3 - Loop Back (LB)
	:
	: : : : : :-> Final bit (F)

25 The set initialization mode (SIM) is used by a  
master or slave station to initialize the master/slave  
session (or communication link). The SIM command puts the  
master and slave stations in the initialization state. Upon  
receiving the SIM command, the receiving station clears the  
send state variable number V(S) and the receive state  
30 variable V(R), thus clearing a retransmit buffer (not

1 shown). The SIM command is used by a station on power-up or  
to clear a lock-up condition of the station. The reset  
initialization mode (RIM) is used by a master or slave  
station to set an information transfer state. This command  
5 also serves as an acknowledgement of the SIM command.

The test message (TM) command is used to test data  
lines. The receiving station responds with a LB command  
which carries (or echoes back) the same data received from  
the message frame where the TM command was active. Failure  
10 of a slave station to echo back the same data received in  
the message frame causes the master station to identify the  
station as disconnected and the station identity and  
location are added to the problem report.

The broadcast (BC) command (bits 2-6) is used by a  
15 master station to transmit data to all slave stations. The  
master station sends this command while the P bit is set to  
a logic zero and the address field of the message frame,  
noted above, contains "FF" hex.

The bit encoding for the INFORMATION field of the  
20 message frame noted above will now be described.  
Preferably, the INFORMATION field consists of four fields  
which identify the priority level of the message frame, the  
station ID, the type of message and data to augment the  
message type:

25

PATH/RSP\_ID:REQ\_ID/DATA/O

The PATH field, shown below in Table VI, may be  
four bytes in length and contains routing information and  
30 frame transition priority data. The transition priority  
data identifies to the CPU the priority level associated

35

1 with the received I-frame. As a result, the system of the  
present invention can prioritize incoming message frames so  
as to organize staff responses thereto in order of priority,  
as will be described in more detail below. The last byte of  
5 this field preferably includes an address expansion bit  
which when set to logic one identifies that the next byte of  
data is the station address field which identifies which  
slave station is sending the message frame.

Table VI

```

10          PATH field bit encoding:
          :7:6:5:4:3:2:1:0:
          : : : : : : : :
          : : : : : : : : > Station Address
          : : :
          : : :————— > Priority: binary 2 - alarm,
                           binary 1 - event/control,
                           binary 0 - data type
          : : :————— >
          : : :
          : : :————— > Address expansion set to logic 1 = next byte
15

```

The RSP\_ID:REQ\_ID field, shown below in Table VII, contains response/request tag (ID) data. Upon receiving a request message (type bit is set to logic 1), the slave station sends a specific response message (e.g., an I-frame). If there is no specific response, the slave station sends generic acknowledgement typically in the form of an S-frame.

Table VII

```

25      RSP_ID:REQ_ID field bit encoding:
      :7:6:5:4:3:2:1:0:
      : : : : : : : :
      : : 1:-:-:-:-> response/request ID
      : :
      : :-----> local master: binary 1 = local master
                        request/response
      :
      :-----> type: logic 1 = request, logic 0 = response

```

30                    Generally, the DATA field may be 128 bytes in  
length and contain application specific data and preferably,  
consists of three fields:

35



## 1                                   LENGTH/DTYPE/TEXT

Where, the LENGTH field, typically 1 byte in length, contains the size in bytes of the DTYPE and TEXT  
5 fields; the DTYPE field, typically one byte in length, contains data codes such as the type of message being sent, e.g., code blue; and the TEXT field which may be 126 bytes in length, contains application specific data, e.g., message data associated with a particular function or station status  
10 data, which is utilized to augment the DTYPE field by identifying a textual message associated with the particular function identified in the DTYPE field. For example, if the DTYPE field identifies a "code blue" code, the TEXT field will include the text which should be displayed on other  
15 stations, such as the staff station.

In the event of a failure within the CPU 2412, the system of the present invention also provides a fail safe feature which is activated upon detection by the nurse control stations 2414, the patient stations 2416 and/or  
20 staff stations 2418. An exemplary embodiment of the configuration for fail safe operation is shown in Fig. 7. In this configuration, fail safe bus (FSB) 3020 is connected between each patient station 2416, each corresponding staff station 2418 and zone indicator assembly 3022. If a failure  
25 occurs in the CPU 2412, each patient station 2416 and corresponding staff station 2418 will fail to receive a polling signal from their corresponding zone controllers. As a result, each station will operate in a local mode utilizing the fail safe bus. When in the local mode,  
30 activation of any of the functions which have access to the fail safe bus will cause a response at a particular patient station, the staff stations and at the zone indicator assembly connected to the group, to allow staff members in

1 the vicinity of the station utilizing the fail safe bus to respond.

An operational flow associated with the above described exemplary fail safe feature will be described with  
5 reference to Figs. 7-9. As noted, upon failure of the CPU 2412, the stations associated with the system of the present invention operate in the local mode. In response to activation of a fail safe device (e.g., the nurse call  
10 button 3250, the code blue switch 3234 or the emergency switch 3232) the system first determines whether the cause of the fail safe was from the activation of nurse call button 3250 of patient control unit 3210 (shown in Fig. 9) (steps 3110 and 3120). Nurse call button 3250, code blue switch 3234 and/or emergency switch 3232 are connected to  
15 patient station 2416 and provide either a general indication to staff members that the patient needs assistance or an emergency indication relating to the patients immediate health condition. Nurse call button 3250 allows the patient to indicate the need for general assistance, whereas, code  
20 blue switch 3234 and emergency switch 3232 allow staff members to activate the appropriate staff response to the patient's health condition. For example, if the patient is experiencing a heart attack a staff member would activate the code blue switch.

25 If the cause of the fail safe was due to the activation of nurse call button 3250, the patient station responds by activating nurse call indicator 3222 of indicator assembly 3220 associated with that particular patient station and by displaying a "nurse call" message on  
30 patient station display 3230 (step 3122). Next, the staff stations 2418 (shown in Fig. 1) associated with the group of patient stations 2416 respond by displaying a "nurse call" message on staff station display 2422 (step 3124). Zone

1 indicator assembly (ZIA) 3022 activates the nurse call  
indicator of zone indicator 3024 (e.g., indicators 1 through  
8, shown in Fig. 7) associated with the particular group of  
patient stations (step 3126). For example, if the nurse  
5 call button is activated by a patient station associated  
with group 1, the nurse call indicator of the group 1 zone  
indicator 3024 associated with zone indicator assembly 3022  
will be activated. Manual reset of the patient station by a  
staff member responding to the call returns the FSB and the  
10 patient stations to the idle local mode (step 3128).

If the cause of the fail safe was not from the  
activation of the nurse call button, the fail safe system  
then determines if the fail safe was caused by the  
activation of emergency switch 3232 (step 3130). If fail  
15 safe operation was caused by the activation of emergency  
switch 3232, patient station 2416 responds by activating the  
emergency indicator associated with that patient station and  
by displaying an "emergency" message on patient station  
display 3230 (step 3132). Preferably, the emergency  
20 indicator is the same indicator as nurse call indicator  
3222. However, activation of indicator 3222 in the  
emergency mode results in a blink light at a predetermined  
rate in pulses per minutes (PPM) as illustrated in the table  
of Fig. 19. Whereas, activation of indicator 3222 in the  
25 nurse call mode results in a steady lamp intensity. Second,  
staff station or stations 2418 associated with the subject  
patient station, displays an "emergency" message on staff  
station display 2422, shown in Fig. 1 (step 3134). Next,  
zone indicator assembly 3022 activates the emergency  
30 indicator of zone indicator 3024 associated with the group  
with which the particular patient station belongs (step  
3136). Staff members responding to the emergency call,

## 34

1 manually reset emergency switch 3232 (step 3138), thus  
returning the fail safe system to the idle local mode.

If, on the other hand, the cause of the fail safe  
was not from the activation of an emergency switch, then,  
5 according to this exemplary embodiment, the fail safe  
operation was activated by code blue switch 3234. The  
patient station responds to the code blue call by activating  
code blue indicator 3228 associated with patient station  
2416 to which the code blue switch is operatively connected,  
10 and by displaying a "code blue" message on patient station  
display 3230 (step 3140). Secondly, staff station or  
stations 2418 associated with the group of patient stations  
2416, displays a "code blue" message on station display 2422  
(step 3142). Zone indicator assembly 3022 also activates  
15 the code blue indicator associated with the subject patient  
station group number (step 3144). Manual reset of code blue  
switch 3234 by the responding staff members returns the fail  
safe bus to the idle local mode (step 3146).

20 NURSE CONTROL STATION

The nurse control portion of the present invention  
will now be described with reference to Figs. 9 and 10.  
Fig. 9 illustrates a system configuration in which  
peripheral equipment is connected to patient station 2416  
25 and in which nurse control station 2414 includes main  
processor 3270, keyboard 3236 and nurse control station  
display 3272. Nurse control station display 3272 can be  
user programmed to perform functions, such as initiating a  
code blue operational sequence, either through keyboard 3236  
30 or direct select keys 3274. The direct select keys 3274  
allow staff members to select specific functions in response  
to menu driven prompts.

1           Fig. 10 is a block diagram which illustrates  
hardware components for nurse control station 2414. Nurse  
control station 2414 includes main processor circuitry 3310,  
keyboard circuitry 3312 and display circuitry 3314. Main  
5   processor circuitry 3310 includes microprocessor 3316, such  
as the 16 bit model 286 microprocessor manufactured by Chips  
& Technology, Inc., 2 Mbytes of memory 3318 having stored  
programs (e.g., system and application programs) and  
communication interface 3320 connected to communication  
10   ports 3322.

          Preferably, communication interface 3320 and  
communication ports 3322 are provided to facilitate data  
communication between zone controller 2420, CPU 2412 and the  
nurse control station 2414. As noted above, the preferred  
15   communication protocol includes the RS-485 serial  
communication protocol. Accordingly, communication  
interface 3320 is configured to accommodate RS-485  
communication utilizing RS-485 drivers/receivers which are  
known in the art.

20           Keyboard circuitry 3312 includes microcontroller  
3324, such as model 8052 manufactured by Intel, which  
includes internal memory having, preferably, 4 Kbytes of ROM  
and 256 bytes of RAM, keypad interface 3326 which is  
connected to keys 3328 and facilitates communication between  
25   a staff member and the nurse control station. Communication  
interface 3330 and communication port 3332 are provided as a  
data communication link to main processor circuitry 3310.  
As noted, the preferred communication protocol includes the  
RS-485 serial communication protocol. Accordingly,  
30   communication interface 3330 is configured to accommodate  
RS-485 communication utilizing RS-485 drivers/receivers  
which are known in the art.

1           Keyboard 3236 (shown in Fig. 9) includes speaker  
3338, handset 3340 and microphone 3342 which facilitate  
audio communication between nurse control station 2414,  
patient stations 2416 and/or staff stations 2418, via audio  
5   controller 3344. The audio circuit portion 3410 of nurse  
control station 2414 will now be described with reference to  
Fig. 11, which illustrates the hardware configuration for  
the audio portion of the keyboard. As shown, audio pair  
3412 from main processor 3270 of nurse control station 2414  
10 (shown in Fig. 9) is connected to the front end of audio  
controller 3344. Preferably, the front end of audio  
controller 3344 includes a coupled 600 ohm balanced  
transformer 3414 which isolates the internal audio circuitry  
of nurse control station 2414 from the external audio  
15 circuits. Depending upon whether the audio signal is being  
received or transmitted, the back end of audio controller  
3344 either directs the audio signal to keyboard speaker  
3338 or to handset 3340, or directs the audio signal from  
microphone 3342 to transformer 3414.

20           Preferably, audio controller 3344 is a 34118 audio  
controller manufactured by Motorola. Audio input signals  
from main processor 3270 of nurse control station 2414,  
which pass through the audio controller are directed to  
keyboard speaker 3338 via amplifier 3416 or to handset 3340  
25 via relay controller 3418 controlled by microcontroller 3324  
(shown in Fig. 10). Audio generated by the nurse control  
station via microphone 3342 or handset 3340 is transferred  
through relay controller 3418 to audio controller 3344 and  
onto the audio pair as shown. The audio pair from keyboard  
30 circuitry 3312 is directed to the equipment panel via main  
processor circuitry 3310, as shown in Fig. 10.

Display circuitry 3314 includes microprocessor  
3346, such as model 8051 manufactured by Intel, memory 3348

1 having stored programs (e.g., system and application  
programs), video controller 3350 which is connected to nurse  
control station display 3272 and facilitates the display of  
the visual communication signals. Select key interface 3352  
5 is connected to direct select keys 3274 and is provided to  
identify to microprocessor 3346 which direct select key 3274  
has been depressed. Communication interface 3354 and  
communication port 3356 are provided as a data communication  
link to main processor circuitry 3310. As noted, the  
10 preferred communication protocol includes the RS-485 serial  
communication protocol. Accordingly, communication  
interface 3354 is configured to accommodate RS-485  
communication utilizing RS-485 drivers/receivers which are  
known in the art.

15

#### PATIENT STATION

The patient station portion of the present  
invention will now be described with reference to Figs. 4, 9  
and 12, 13, 14A and 14B. Turning initially to Fig. 9,  
20 patient station 2416 is a microprocessor controlled  
interface between CPU 2412, the patient bedside equipment  
and peripheral equipment. The communication link between  
CPU 2412 and the bedside or peripheral equipment is via the  
master/slave communication link described above. Examples  
25 of the patient bedside equipment include heart monitors,  
respirators, pulse oxymeters or I.V. pumps which include  
data communication ports to serially transmit data.  
Examples of peripheral equipment include patient control  
unit 3210, staff presence switch 3254, indicator assembly  
30 3220, code blue switch 3234, emergency code switch 3232  
and/or a smoke detector (not shown). Staff presence switch  
3254 is preferably located by the door of the patient rooms  
and is provided to activate indicator 3220 and to cause

35

1 patient station 2416 to send a message frame to CPU 2412  
indicating the particular type of staff member who is  
present in the patient's room, as will be described in more  
detail below. In addition, patient station 2416 may be  
5 operatively connected to a side-rail communication system  
(not shown) installed in a side-rail of the patient's bed,  
as well as bed sensors which sense whether the patient is in  
the bed. Side-rail communication system may be connected to  
the audio output ports 3624, shown in Fig. 13, to facilitate  
10 audio communication at the side-rail.

Fig. 12 is a circuit block diagram for the patient  
station circuitry 3510 installed within patient station  
2416. The patient station circuitry 3510 includes  
microprocessor 3512, such as model 64180 manufactured by  
15 Motorola operating at a frequency of 12.888 MHz. via crystal  
3514, 96 Kbytes of memory 3516 (e.g., 64 Kbytes of flash ROM  
and 32 Kbytes of RAM) having stored programs, e.g., system  
and application programs. In this exemplary configuration,  
the data and address buses of the microprocessor are  
20 connected to memory, e.g., RAM 3518 and an EPROM 3520.  
Memory decoder 3522 is utilized to select between RAM 3518  
and EPROM 3520 in response to a particular address on the  
address bus. The address bus is also connected to a pair of  
latches 3524 and 3526 which interface the microprocessor to  
25 status indicators, the fail safe bus (FSB), the audio  
control circuitry, and to switches and other peripheral  
equipment connected to the patient station, as shown. In  
addition, I/O decoder 3528 is utilized to select between  
either latch in response to a particular address on the  
30 address bus. Incoming signals from the above noted  
peripheral equipment are received by buffer 3530 and then  
transferred to the data-bus upon being enabled by I/O  
decoder 3528.



1 Utilizing the preferred microprocessor 3512 (i.e.,  
the Motorola 64180), serial communication between the zone  
controller 2420 and microprocessor 3512 or between the  
bedside equipment and microprocessor 3512, may be  
5 accomplished through either one of two asynchronous serial  
communication ports 3532 and 3534 which are, preferably,  
configured to RS-485 protocol utilizing RS-485  
driver/receivers (RS-485 D/R) 3536 and 3538 as shown.

Fig. 13 is a circuit block diagram for the audio  
10 portion 3610 of patient station 2416. As shown, audio pair  
3612 from an equipment panel (e.g., audio matrix 2510 shown  
in Fig. 2) is connected to the front end of audio controller  
3614. Preferably, the front end of audio controller 3614  
includes a coupled 600 ohm balanced transformer 3616 which  
15 isolates the internal audio circuitry of patient station  
2416 from the external audio circuits. Depending upon  
whether the audio signal is being received or transmitted,  
the back end of audio controller 3614 either directs the  
audio signal to patient station speaker 3618 or to an  
20 external audio speaker, such as speaker 3252 of patient  
control unit 3210, shown in Fig. 9, or directs the audio  
signal from microphone 3620 to transformer 3616.

Preferably, audio controller 3614 is a 34118 audio  
controller manufactured by Motorola. Audio input signals  
25 from audio matrix 2510 which pass through the audio  
controller are directed to patient station speaker 3618 via  
amplifier 3622 and/or to audio output ports 3624 via  
amplifier 3626 and relay controller 3628. Audio signals  
generated by the patient station via microphone 3620 are  
30 selectively transferred through audio controller 3614 onto  
the audio pair as shown. Mute switch 3630 may be provided  
to allow a staff member to manually short out the microphone  
so as to prevent audio signals from being generated at the

1 patient station. In addition, the audio circuitry for the  
patient station may include input audio ports 3632 which  
facilitate a connection between external entertainment  
equipment, such as a television or a radio, and audio output  
5 ports 3624 via relay switch 3628. To illustrate, audio  
signals from a television in the patient's room can be  
directed from patient station 2416 to speaker 3252 in  
patient control unit 3210 (shown in Fig. 9) to bring the  
audio from the television closer to the patient.

10 Referring again to Fig. 9, each patient station  
2416 may be coupled to external peripheral equipment, such  
as controllers, indicators and/or switches, which provide  
medical instrument data and/or patient status data to staff  
members and which facilitate patient control of  
15 environmental facilities within the patient's room, as will  
be described below. Figs. 14a and 14b represent an  
exemplary operational flow-chart of the interaction between  
the patient station and the bedside equipment and between  
the patient station and the CPU so as to facilitate  
20 communication between the bedside equipment and the CPU.  
Initially, the patient station monitors the inputs from the  
external peripheral equipment (e.g., switches) to determine  
if the equipment has been activated (steps 3710 and 3720).  
If a switch or other peripheral equipment is activated, a  
25 message frame associated with the activated switch will be  
stored in the memory of patient station circuitry 3510,  
shown in Fig. 12 (step 3722) and transferred to zone  
controller 2420. If, on the other hand, a switch has not  
been activated then the patient station will poll the  
30 bedside equipment via serial port 3534 (shown in Fig. 12)  
for status or message information and interpolate field  
parameters onto the received message (step 3724 and 3726).  
The message frame is then stored in patient station memory

1 3516 (shown in Fig. 12) and remains therein until the  
patient station 2416 is polled by the zone controller 2420  
corresponding to the patient station (steps 3728, 3730 and  
3732).

5           Once polled, the patient station transfers the  
message frame to the S-RAM 2512 (shown in Fig. 2) of the  
zone controller until the last byte of the frame has been  
transferred (i.e., the F bit is set to logic 1) (steps 3734  
and 3736). The zone controller then determines if the  
10 message frame, received is an S-frame or an I-frame, and if  
the message frame is an S-frame the zone controller  
acknowledges the message frame and the patient station  
returns to monitor the switch inputs (steps 3738 and 3740).  
If the received message frame is an I-frame the frame is  
15 transferred to the CPU which determines whether a response  
to the transmitting station is required (steps 3742, 3744  
and 3746). If no response is required the CPU stores the  
received data and the patient station returns to monitor the  
switch inputs, as shown. If, however, a response is  
20 required a response message frame is sent to the zone  
controller and stored in the S-RAM (step 3748). The zone  
controller polls the patient station and if a received ready  
(RR) command is received in return, the response message  
frame is transferred to and stored in the patient station  
25 (steps 3750 and 3752).

          Once the response message frame is received the  
patient station performs the task associated with the  
information in the frame (step 3754). In addition to  
sending a response message to the patient station, the CPU  
30 may also be required to send a message frame to the nurse  
control station to alert staff members of potential faults  
either through tone and visual indications similar to those

1 illustrated in Fig. 18 or by adding the information to the  
problem report described above (step 3756).

Referring again to Fig. 9, in the preferred  
embodiment, patient station 2416 is connected to patient  
5 control unit 3210 via data link 3246. Patient control unit  
3210 includes control buttons 3248 which facilitate patient  
control of the environmental facilities within the patient's  
room, via patient station 2416 and CPU 2412. Such  
environmental facilities include, for example, the  
10 television, radio, draperies and the room lighting.

Nurse call button 3250 is provided to enable the  
patient to call the nurse control station or stations within  
the group. As noted above, the communication between  
stations is facilitated by CPU 2412 utilizing the  
15 master/slave communication link described above.

Fig. 15 illustrates an exemplary operational flow  
for the patient control unit 3210 in combination with  
patient station 2416. Upon activation of nurse call button  
3250 of patient control unit 3210 (shown in Fig. 9), patient  
20 station 2416 receives the switch activation data via data  
link 3246 and buffers 3530 (shown in Fig. 12).

Microprocessor 3512 then interpolates field data onto the  
received message to form a message frame, as described  
above, and stores the message frame in RAM 3518 (step 3810).

25 Once stored in memory, the nurse call data remains  
therein until the patient station is polled by the zone  
controller (step 3820). Once polled, the message frame is  
then transferred to the zone controller and stored in the S-  
RAM (step 3830). The data remains in the S-RAM until the S-  
30 RAM is polled by CPU 2412, upon which, the message frame is  
then transferred to the CPU (step 3840).

Reception of the message frame in the CPU causes  
the CPU to begin the station task identified in the

1 INFORMATION field of the I-frame (step 3850), to determine  
the message received from the patient station and provide an  
appropriate response thereto (steps 3860 and 3870). For  
this example, CPU 2412 is responding to the activation of  
5 nurse call button 3250 of patient control unit 3210. The  
initial response to the activation of the nurse control  
button is to return a message frame to the patient station  
to activate nurse call indicator 3222 of indicator assembly  
3220 (shown in Fig. 9). In addition, the CPU prioritizes  
10 the message frame utilizing the transition priority data of  
the PATH field and then sends to the nurse control station  
or stations connected in the group associated with the  
patient station, a message frame including tone and display  
data identifying the patient and the associated room number  
15 (steps 3880 and 3890). At this point, the station task is  
completed and the CPU returns to the listen task. Manual  
reset of the patient station by a responding staff member  
deactivates indicator 3222 and clears the message from the  
nurse control station display.

20 Referring once again to Fig. 9 patient station  
2416 may also be connected to staff presence switch 3254,  
indicator assembly 3220, code blue switch 3234 and/or  
emergency code switch 3232. In the configuration shown,  
staff presence switch 3254 is connected to patient station  
25 2416 via data link 3256 and when properly activated provides  
patient station 2416 with a signal indicative of the type of  
staff member present in the patient's room. Once activated,  
a message frame (e.g., an I-frame) is transferred to the CPU  
and an appropriate response is returned to that particular  
30 patient station, in a manner described above.

The responding frame from the CPU 2412 includes  
information to cause the activation of an indicator in  
indicator assembly 3220 which corresponds with the type of

1 staff member in the patient's room. To illustrate, if the  
staff member entering the patient room is a registered nurse  
(RN), that person would activate switch 3258 which in turn  
would activate indicator 3224 of indicator assembly 3220 via  
5 patient station 2416 and CPU 2412. If the staff member  
entering the room is a licensed practical nurse (LPN), that  
person would activate switch 3260 of staff presence switch  
3254, which in turn would activate indicator 3226 of  
indicator assembly 3220 via patient station 2416 and CPU  
10 2412. If, on the other hand, the staff member entering the  
room is an aide, then that person would activate switch 3262  
of staff presence switch 3254, which in turn would activate  
indicator 3228 of indicator assembly 3220. When the staff  
member leaves the patient's room, the particular staff  
15 member switch is deactivated so as to deactivate indicator  
assembly 3220.

In the preferred embodiment, indicator assembly  
3220 is a four lamp light fixture (e.g., a dome lamp) having  
colored lenses associated with each lamp. The fixture is  
20 secured or otherwise positioned on the wall outside the  
patient's room, preferably above the doorway, to allow staff  
members in the hallway to simply look at each indicator  
assembly and determine the type of staff member in a  
particular patient's room, if any. Alternatively, the  
25 indicator assembly may be any known type sufficient to  
provide staff members with an indication as to the type of  
staff member in a patient's room, for example, the indicator  
may be a LCD display which identifies the type and the name  
of the staff member in the patient's room in response to  
30 information provided to the system by the above described  
staff locator system, described in more detail in commonly  
assigned U.S. Application Serial No. 07/924,101, filed  
August 3, 1992, which is a continuation-in-part of copending

1 U.S. Patent Application Serial No. 07/559,196, filed on July  
27, 1990, the disclosure of which is incorporated herein by  
reference.

Code blue switch 3234 and emergency code switch  
5 3232 are connected to patient station 2416 via data links  
3264 and 3266, respectively, as shown in Fig. 9, and are  
provided to allow staff members to initiate code blue or  
emergency responses directly from the patient's room. As  
noted above, code blue and/or emergency code procedures may  
10 also be initiated from nurse control station 2414.  
Initiation of the code blue response procedure at a patient  
station 2416 will result in the following occurrences.  
Initially the code blue data signal received from the code  
blue switch is stored in the patient station memory as a  
15 message frame, in a manner described above. The  
microprocessor 3512 (shown in Fig. 12) in the patient  
station 2416 then waits to be polled from the zone  
controller 2420 before transferring the data to the zone  
controller. Once polled by zone controller 2420 the message  
20 frame is transmitted to the zone controller and stored in  
the S-RAM 2512 until the S-RAM is polled by CPU 2412. Once  
the message frame is received within the CPU the message  
frame is prioritized and the station task associated with  
the data within the INFORMATION field of the message frame  
25 is initiated.

An example of a station task performed by the CPU  
in response to the activation of a code blue switch will be  
described below. Initially CPU 2412 determines the message  
type received from zone controller 2420. Next the CPU  
30 performs whatever function is associated with the message,  
in this example the message relates to the code blue  
function. In response to the code blue function, the CPU  
2412 sends to the particular patient station an I-frame

1 which includes data to cause activation of particular  
peripheral equipment as well as devices within the patient  
station 2416, e.g., a tone code and an indicator assembly  
activation code. Next CPU 2412 determines which staff  
5 station or stations 2418 and which nurse control station or  
stations 2414 are grouped with the subject patient station  
2416. Thereafter, CPU 2412 sends to each associated staff  
station an I-frame including message data to display "code  
blue" on staff station display 2422 of staff station 2418.  
10 Next CPU 2412 sends a message to the ZIA 3022, shown in Fig.  
7, to activate the proper indicator associated with the  
patient station group in a manner similar to that described  
above with reference to fail safe bus 3020.

The CPU 2412 then sends an I-frame to each nurse  
15 control station grouped with the patient station to display  
the room number and identity of the patient subject to the  
code blue function, on the display of the nurse control  
station. The CPU 2412 then sends to the nurse control  
station an I-frame including appropriate control signals  
20 associated with the patient station message. Once the above  
steps are accomplished the station task is completed and the  
CPU 2412 returns to the listen task.

The system of the present invention may also be  
configured to monitor medical equipment being used to treat  
25 the patient (i.e., bedside equipment). Such bedside  
equipment may be connected to communication port 3534 (shown  
in Fig. 12) of patient station 2416. In instances where the  
serial data from the bedside equipment is not configured for  
RS-485 protocol, serial data converter 2520 (shown in Fig.  
30 2) may be interconnected between serial port 3854 of patient  
station 2416 and the serial port of the bedside equipment.  
Typically, the serial port of the bedside equipment is  
configured to operate with RS-232 protocol, thus, serial



1 data converter 2520 would be an RS-485 to RS-232 converter  
which is known in the art.

Examples of the above described bedside equipment  
are shown in Figs. 9. As shown, a heart rate monitor 3280  
5 is connected to patient station 2416 via data link 3282,  
which as noted above is operatively connected to nurse  
control station 2414 via zone controller 2420 and CPU 2412.  
The patient station (acting as a master station) polls heart  
rate monitor 3280 (operating as a slave station) to verify  
10 that the patients heart rate falls within the proper range  
as determined by the monitor. The zone controller  
periodically polls patient station 2416, as described above  
for an S-frame or an I-frame message frame. Typically with  
respect to this example, if no fault is detected the patient  
15 station will respond to the polling of the zone controller  
with an S-frame indicating proper operation of heart rate  
monitor 3280. However, a fault detected in monitor 3280  
will be stored in RAM 3518 of patient station circuitry 3510  
(shown in Fig. 12) along with the appropriate field data in  
20 the form of an I-frame, and the I-frame is transferred to  
zone controller 2420 and CPU 2412 in a manner described  
above. The CPU then analyzes the I-frame and an appropriate  
alarm sequence is initiated to notify staff members at nurse  
control station 2414 of the detected fault.

25 As another example, an intravenous (IV) pump 3284  
is connected to patient station 2416 via data link 3286,  
which as noted above is operatively connected to nurse  
control station 2414, via zone controller 2420 and CPU 2412.  
In this example, the IV pump is periodically monitored by  
30 patient station 2416 to ensure the flow rate of the pump is  
appropriate. If a failure is detected, a message frame  
including the error message is transferred to CPU 2412 in a  
manner set forth above. The CPU then initiates an

1 appropriate alarm sequence, such as displaying a message on  
the monitor of nurse control station 2414, that the IV  
container is empty and needs to be changed. It should be  
noted, that numerous other types of bedside equipment may be  
5 monitored by the system of the present invention, including  
respirators and heart monitors.

Transmitter 3290 is hardwired to the bedside  
equipment, e.g., heart rate monitor 3280, and is provided to  
enable a central computer system to determine what room or  
10 other area of the health care facility the bedside equipment  
is located and to transmit operation data generated by the  
bedside equipment, such as status data or other data  
associated with the operation of the equipment. In this  
configuration, transmitter 3290 transmits an identification  
15 signal and the operation data to an IR transceiver which is  
in communication with the central computer through a network  
server as described in Application Serial No. 07/924,101.  
The central computer determines which transceiver received  
the identification signal of the bedside equipment and  
20 transfers the location data of the equipment and the  
operation data to CPU 2412 via data link 2728 (shown in Fig.  
4). Transmitter 3290 may be a radio frequency transmitter  
operating at a frequency of approximately 300 MHz, which are  
available from Dallas Semiconductor, Inc.

25

#### STAFF STATION

Referring again to Fig. 1, staff station 2418 is  
similar in design to patient station 2416. In the preferred  
embodiment, staff station 2418 may be configured, in the  
30 initial system configuration setup, to operate in a "duty"  
mode or a "staff" mode. In the "duty" mode staff station  
2418 provides patient call indications on staff station  
display 2422, as well as facilitating communication with

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1 nurse control station 2414. In the "staff" mode staff  
station 2418 facilitates communication with nurse control  
station 2414.

Fig. 16 illustrates hardware configurations for  
5 the staff station circuitry 3910 installed within staff  
station 2418. The staff station circuitry 3910 includes  
microprocessor 3912, such as model 64180 manufactured by  
Motorola operating at a frequency of 12.888 MHz. via crystal  
3914, 96 Kbytes of memory 3916 (e.g., 64 Kbytes of flash ROM  
10 and 32 Kbytes of RAM) having stored programs, e.g., system  
and application programs. In this exemplary configuration,  
the data and address buses of the microprocessor are  
connected to the memory, e.g., RAM 3918 and an EPROM 3920.  
Memory decoder 3922 is utilized to select between RAM 3918  
15 and EPROM 3920 in response to a particular address on the  
address bus. The address bus is also connected to a pair of  
latches 3924 and 3926 which interface the microprocessor to  
status indicators, the fail safe bus (FSB), the audio  
control circuitry, and to switches and other peripheral  
20 equipment connected to the staff station, as shown. In  
addition, I/O decoder 3928 is utilized to select between  
either latch in response to a particular address on the  
address bus. Incoming signals from the above noted  
peripheral equipment are received by buffer 3930 and then  
25 transferred to the data-bus upon being enabled by I/O  
decoder 3928.

Utilizing the preferred microprocessor (i.e., the  
Motorola 64180), serial communication between the zone  
controller and the microprocessor may be accomplished  
30 through asynchronous serial communication port 3932 which  
is, preferably, configured to RS-485 protocol utilizing RS-  
485 driver/receiver (RS-485 D/R) 3934 as shown.

## 50

1           Fig. 17 illustrates hardware configurations for  
the audio portion 4010 of staff station 2418. As shown,  
audio pair 4012 from an equipment panel (e.g., audio matrix  
2510 shown in Fig. 2) is connected to the front end of audio  
5   controller 4014. Preferably, the front end of audio  
controller 4014 includes a coupled 600 ohm balanced  
transformer 4016 which isolates the internal audio circuitry  
of staff station 2418 from the external audio circuits.  
Depending upon whether the audio signal is being received or  
10   transmitted, the back end of audio controller 4014 directs  
the audio signal to staff station speaker 4018 or directs  
the audio signal from microphone 4020 to audio matrix 2510  
via audio controller 4014.

          Preferably, audio controller 4014 is a 34118 audio  
15   controller manufactured by Motorola. Audio input signals  
from audio matrix 2510 which pass through the audio  
controller are directed to staff station speaker 4018 via  
amplifier 4022. Audio generated by the staff station via  
microphone 4020 is selectively transferred through audio  
20   controller 4014 onto the audio pair as shown. Mute switch  
4024 may be provided to allow a staff member to manually  
short out the microphone so as to prevent audio signals from  
being generated at the patient station.

#### SYSTEM FUNCTIONS

25           The patient care and communication system of the  
present invention may be programmed to perform numerous  
operations associated with patient care and communications  
within a hospital or other health care facility. The  
following functions are exemplary of the numerous types of  
30   features and the functional flow (or data exchange) between  
the different stations, the CPU and the zone controller  
utilize the above described preferred master/slave  
communication link.

1           a.    Call Priority

          Message frames usually in the form of an I-frame  
          originated by a nurse control station, a patient station  
          and/or a staff station are interpreted by CPU 2412 and  
5   assigned a priority level based upon the type of message  
          frame received (i.e., the DTYPE field of the INFORMATION  
          field contains the message type which corresponds to the  
          priority level that will be assigned to the frame). In  
          addition, the message associated with the TEXT field of the  
10   message frame is displayed on nurse control station display  
          3272 of a nurse control station 2414 in order of priority  
          level. The priority levels are preprogrammed during the  
          initial set-up of the system configuration, but may be  
          altered by staff members at nurse control station 2414 via  
15   keyboard 3236 or direct select keys 3274 (shown in Fig. 9).  
          The highest priority call will be displayed first and other  
          calls will follow in descending order according to the  
          priority level.

          Preferably, each call originated has specific  
20   audible and visual signaling based on the call priority  
          level which are distributed to the necessary nurse control  
          stations, zone indicator assembly, patient stations and/or  
          staff stations via CPU 2412 and their respective zone  
          controller. Figs. 18-20 represent tables illustrating  
25   exemplary embodiments of call priority levels, their  
          associated visual and tone indications which are generated  
          at either the nurse control station, the patient station  
          and/or the staff station. Fig. 18 illustrates the preferred  
          visual display which appear on nurse control station display  
30   3272 and the tones generated at speaker 3238 (shown in Fig.  
          9) in response to the various priority levels. For example,  
          in response to the activation of code blue switch 3234  
          (shown in Fig. 9) CPU 2412 will transmit to nurse control

1 station 2414 a message frame instructing the nurse control  
station to display on the nurse control station display 3272  
a flashing arrow directed at a direct select key 3274 to  
indicate which key will enable the staff member to connect  
5 the audio of the nurse control station to the audio of the  
patient station and respond to the call. The arrow will  
flash at a rate of approximately 120 pulses per minute  
(PPM). In addition, the room number and bed number  
associated with the patient station to which the code blue  
10 switch is connected and the "CODE BLUE" message will be  
displayed on nurse control station display 3272. An audible  
tone at the rate of 120 PPM will also be generated at  
speaker 3238 of nurse control station 2414.

The preferred response at patient station 2416,  
15 shown in Fig. 19, to the activation of the code blue switch  
will be to pulse a station call and bed call placement LED  
indicators (not shown), which may be positioned on the front  
panel of patient station 2416, at a rate of 120 PPM, and to  
pulse a code blue indicator of the corresponding group  
20 indicator assembly 3024 via ZIA 3022 (shown in Fig. 7) at a  
rate of 120 PPM.

The preferred response at staff station 2418,  
shown in Fig. 20, to the activation of the code blue switch  
will be to pulse an incoming call LED indicator which may be  
25 positioned on the front panel of staff station 2418, at a  
rate of 120 PPM, to display on staff station display 2422  
(shown in Fig. 1) the room and bed number associated with  
the patient station to which code blue switch 3234 is  
connected and to display the "CODE BLUE" message; to pulse a  
30 blue indicator of the corresponding group indicator assembly  
3024 via ZIA 3022, at a rate of 120 PPM; and to generate an  
audible tone at the rate of 120 PPM at speaker 4018 of staff  
station 2418 (shown in Fig. 1).

1           b.    Nurse Follow

          The nurse follow feature allows a staff member to selectively direct incoming calls to a particular nurse control station to selected patient stations and/or staff  
5   stations. To illustrate, this feature may allow the staff member to program the nurse control station to distribute incoming calls to a single patient station, to patient stations where particular staff members have activated  
10   respective staff presence switches (e.g., switch 3254, shown in Fig. 9) and/or to all patient or staff stations assigned to the group associated with the particular nurse control station. Thus, when a staff member is required to leave the area of a nurse control station, incoming calls to the nurse control station can be routed to locations where appropriate  
15   staff members can respond to the call.

          In operation, a staff member attending nurse control station 2414 may utilize direct select keys 3274 (shown in Fig. 9) in response to menu driven prompts to configure the system to operate in the nurse follow mode.  
20   In the nurse follow mode, calls which are directed to the nurse control station 2414 via CPU 2412 and corresponding zone controllers 2420 will automatically be routed to the station or stations selected by the staff members or to stations in locations where that staff member or other staff  
25   members are determined to be present by staff locator system 2428 (shown in Fig. 4 and described in U.S. Application Serial No. 07/924,101).

          For example, if the staff member selects the nurse follow feature which routes incoming calls to patient  
30   stations where the RN switch 3258 of staff presence switch 3254 (shown in Fig. 9) has been activated, CPU 2412 will direct the incoming call to the nurse control station to any

1 room in the group where switch 3258 of staff presence switch  
3254 has been activated.

As another example, CPU 2412 of the patient care  
and communication system interacts with the central computer  
5 system of staff locator system 2428, shown in Fig. 4. In  
this configuration, the identification badges are in  
communication with the central computer system in a manner  
described in Application Serial No. 07/924,101, which is  
incorporated herein by reference. In particular, Figs. 4  
10 and 17c of that application, show the identification badge  
1111, which is worn by the staff member, continually  
transmits the identification signal (of the staff member)  
and the central computer system continually monitors the  
identification signal to update the location of the badge  
15 (and the staff member). The location information of the  
staff member is transferred to CPU 2412 via data link 2726  
(shown in Fig. 4) which may be any known type of  
communication link utilized to facilitate communication  
between computer systems. Therefore, when a call is  
20 directed to a nurse control station 2414 programmed to  
operate in the nurse follow mode, CPU 2412 will route the  
incoming call to a station (either 2416 or 2418) positioned  
nearest the detected location of the staff member. In an  
alternative embodiment, a staff member attending the nurse  
25 control station may want to route incoming calls to  
locations of other staff members. In this embodiment, the  
nurse control station can be programmed in the nurse follow  
mode to route the incoming calls intended for nurse control  
station 2414, to stations where the other staff members have  
30 been detected by the staff locator system.



1           c.    Voice Paging

          The voice page feature allows staff members to  
communicate to selected patient and/or staff stations from  
the nurse control station. To illustrate, this feature  
5   allows a staff member to communicate to all staff members  
who have activated staff presence switches associated with  
the nurse control station (i.e., within the same group) and  
all staff members in areas where staff stations are located.  
Fig. 21 illustrates an exemplary operational flow for the  
10   voice paging feature of the present invention. Initially,  
the staff member desiring to page all staff members within  
the assigned group, programs nurse control station 2414 via  
direct select keys 3274 (shown in Fig. 9) which activate  
menu driven functions (step 4410). The menu driven  
15   instructions from the nurse control station are then  
transferred to the CPU via zone controller 2420 in a manner  
described above (step 4420). The CPU analyzes the  
instructions, e.g., determines the identification of the  
patient and/or staff stations and their associated zone  
20   controllers and the CPU performs the function associated  
with the received message frame (step 4430, 4440 and 4450).  
Thereafter, the CPU causes the audio connection between each  
station and the nurse control station and notifies the  
paging staff member to begin talking (steps 4460 and 4470).  
25           Alternatively, the voice paging feature may  
utilize staff locator system 2428, shown in Fig. 4 to  
determine the location of a staff member or members so that  
the staff member attending nurse control station 2414 may  
communicate with the patient and/or staff stations nearest  
30   to each staff member or members being paged.

1           d.    Room Monitoring

          The room monitoring feature allows staff members attending a nurse control station 2414 to activate the audio system of either a selected number of patient stations 2416  
5   or to manually step or automatically scan through each patient station 2416 in each room associated with the station grouping, described above, in a predetermined order for a predetermined period of time so as to activate microphone 3520 of patient station 2416, enabling staff  
10 members to listen for sounds of distress or other uncharacteristic noises so as to check on the well being of a patient or patients. Preferably, the predetermined order for monitoring rooms is from the lowest room number to the highest and the predetermined period of time is  
15 approximately ten seconds. In operation, the staff member attending nurse control station 2414 configures the system for automatic room monitoring by depressing direct select keys 3274 of nurse control station display 3272 in response to menu driven prompts. Once configured for automatic  
20 monitoring, CPU 2412 sends a message frame to each patient station in the above noted order to activate microphone 3620 (shown in Fig. 13) of audio circuitry 3610, via audio controller 3614, for a period of ten seconds to allow the attending staff member to listen for distress noises and  
25 other uncharacteristic noises.

DIAGNOSTICS

          The system of the present invention also provides diagnostic features which continuously monitor system  
30 components. As noted above, system faults are communicated to the nurse control station and/or to the staff station and added to the problem report. Hard and/or soft copies of the problem report may be obtained from printer 2724 and/or

1 external computer 2722 (shown in Fig. 4) or the problem  
report may be displayed on nurse control station display  
3272 when the "problem reports" feature is selected by  
direct select keys 3274 shown in Fig. 9.

5 In addition, the operation of selected periphery  
devices in the patient's room are continuously monitored and  
any failures are brought to the attention of the staff  
member at a nurse control station within the group. For  
example, the wiring to code blue switch 3234, the smoke  
10 alarm and/or the nurse call button 3250 on patient control  
unit 3210 may be monitored for damaged to the wires between  
such periphery devices and patient station 2416.

Fig. 22 shows the hardware components for patient  
control unit 3210 which is connected to patient station  
15 2416. Preferably, the wiring is tested by microprocessor  
3512 (shown in Fig. 12) activated signals in combination  
with the wire test circuitry 4510. Wire test circuit 4510  
includes resistor 4512 and field effect transistor (FET)  
4514 which are connected between call wire 4516 and nurse  
20 call wire 4518, as shown. In this configuration,  
microprocessor circuitry 3510 of patient station 2416, shown  
in Fig. 12, periodically turns on FET 4514 via call wire  
4516 therefore completing the ground path connecting call  
wire 4516 and nurse call wire 4518. Microprocessor 3512  
25 then interrogates nurse call wire 4518 via buffer 3530  
(shown in Fig. 12) in response to microprocessor driven  
instructions, so as to perform a continuity check of the  
nurse call feature of patient control unit 3210.  
Preferably, the period between each wire test is two  
30 seconds. Wire test circuit 4510 may be utilized to perform  
wire tests between any periphery equipment and the processor  
associated with the station to which the peripheral  
equipment is connected. In the event the continuity check

1 fails, a failure alarm sequence is initiated to notify staff  
members of the wire failure and which wire in which  
periphery device has failed.

The patient care and communication system of the  
5 present invention also includes external diagnostic device  
2570 connected to serial data converter 2520, as shown in  
Fig. 2. Preferably, external diagnostic device 2570 is a  
modem provided to facilitate external diagnostics of the  
patient care and communication system of the present  
10 invention, via converter 2520 and zone controller 2560.  
External diagnostic device 2570 allows a technician or other  
service personnel to remotely verify and update the  
configuration of the system in a manner similar to that  
performed by staff members attending a nurse control  
15 station. In addition, the external diagnostic device 2570  
allows the technician or other service personnel to view the  
system problem report which, as noted above, includes  
information as to which stations or equipment are not  
operational.

20

#### STATIONS WITH PBX TELEPHONE INTERFACE

An alternative embodiment for the system  
configuration is shown in Figs. 23 and 24. In this  
embodiment a private-branch exchange (PBX) 2430 is connected  
25 to nurse control stations 2414, patient stations 2416 and  
staff stations 2418 for providing staff-to-staff, staff-to-  
patient and/or external telephone communications for the  
hospital environment. The PBX 2430 also connects to a  
plurality of telephones throughout the facility and to or  
30 from external telephone lines of the telephone local  
exchange or central office. The components of a PBX for  
processing data and controlling the telephone operations are  
well known. The PBX according to the present invention

35

1 includes a processor, associated memory and stored programs.  
The preferred PBX according to the present invention is the  
IDS-228, manufactured by EXECUTONE Information Systems, Inc.  
Each station is provided with a PBX interface which  
5 facilitates PBX telephone or voice communications  
therebetween. System data communications are accomplished  
in a manner described above utilizing zone controllers 2420  
and the above described protocol.

Fig. 25 is a circuit block diagram of the patient  
10 station 2416 according to the alternative embodiment, which  
includes a telephone circuit 4610, which in turn connects to  
the PBX 2430. The patient station further includes a  
receiver unit 4800 for sensing or receiving signals  
transmitted from the portable badges. As shown, the patient  
15 station 2416 is a microprocessor controlled interface having  
similar system data communications as the patient station  
described above with reference to Figs. 4, 9 and 12-14b.  
Further, the telephone circuit 4610 facilitates telephone  
communication between a patient via patient station control  
20 unit 3210, shown in Fig. 23, and the internal and external  
telephone systems via PBX 2430, shown in Fig. 24.

According to the alternative embodiment, the  
receiver unit 4800 receives wireless electromagnetic  
transmissions, preferably infrared and frequency modulated  
25 (FM), from a portable transmitter. The transmissions from  
the portable transmitter include transmitter ID signals.  
The receiver in turn forwards an information packet  
including the received transmitter ID signals to the central  
processing unit 2412 which determines the identity and  
30 location of the transmitter. The information packet from  
the receiver 4800 is preferably forwarded to the central  
processing unit 2412 through zone controller 2420.  
Alternatively, the information packet is forwarded to the

1 PBX 2430 through telephone circuit 4610. According to the  
alternative embodiment of the present invention, the PBX  
2430 is capable of processing the information packet from  
the receiver 4800 to determine the identity and location of  
5 the transmitter, both independently from or as a shared  
resource of the central processing unit 2412. Of course,  
the information packet from the receiver 4800 may be  
forwarded to the central processing unit 2412 via the PBX  
2430 or vice versa.

10 Typically, telephone voice and data communication  
between each station and the PBX 2430 is in the form of  
message frames which are divided into fields, e.g., a data  
field and a control field. As an example, the data field  
associated with voice data to the station is approximately  
15 64 kilobits in length and the control field is approximately  
2 kilobits in length. The control field includes a sync bit  
for synchronizing communications between the telephone and  
the PBX. The preferred transmission rate for data is 19.2  
kilobits per second.

20 According to the alternative embodiment, a robbed  
bit signaling technique is utilized for transferring data  
from the patient, staff or nurse control station to the PBX.  
For example, utilizing this technique, one bit within every  
fourth transmission of the voice/data stream is utilized for  
25 the transmission of the system data. Thus the effective  
data transmission rate of the control data is approximately  
2 kilobits per second.

Figs. 26-28 illustrate typical system timing and  
format diagrams for the communication of data frames between  
30 the stations of the present invention and the PBX 2430. As  
shown in Fig. 26, the data transmitted from the  
microprocessor or microcontroller (hereinafter identified as  
"microprocessor") within each station is configured in a 16

1 bit parallel data word on the microprocessor data bus, which  
is preferably framed by one (1) start bit and seven (7) stop  
bits. Communications with the PBX system, on the other  
hand, are in a serial mode, therefore, the 16 bit parallel  
5 data word is converted to a serial data stream in the  
telephone circuit within each station, via parallel-to-  
serial converter 4620, shown in Fig. 25. In addition, a  
synchronization bit (sync bit) is added into each  
microprocessor data frame to maintain clock alignment  
10 between the PBX and the station.

Preferably, telephone voice transmissions between  
the PBX and the telephone are in the PCM format which may  
utilize the primary, secondary or both channels. As shown  
in Fig. 25, PCM CODEC 4630 compresses the voice information  
15 into PCM format. Transmitter conditioner 4640 amplifies and  
modulates each frame for transmission to the PBX 2430. The  
primary channel is preferably a 64 kilobits channel used to  
transfer control information to and from peripheral devices  
(e.g., the PBX), a synchronization bit for the hardware, and  
20 the voice signal. The secondary channel is also a 64  
kilobit channel which is utilized to transfer EIA data and  
controls for serial communications, such as for RS-232  
applications.

Figs. 27 and 28 illustrate exemplary message frame  
25 formats and timing in an expanded form for telephone voice  
and data information between each station and the PBX. As  
shown in Fig. 27, data from the microprocessor is in a 16  
bit parallel format and is framed by one start bit and seven  
stop bits to form the microprocessor (uP) data frame, where  
30 each uP data frame is approximately 8ms in length.  
Telephone voice, data and information packet including  
transmitter ID from microprocessor 3510, shown in Fig. 25,  
is then converted to a serial data bit stream via parallel-

1 to-serial converter 4620 which then transfers the serial  
signal to transmitter conditioner 4640. Transmitter  
conditioner 4640 amplifies and modulates the PCM signal for  
transmission to the PBX 2430 via the 4-pair telephone wire.

5 An exemplary embodiment of the format and timing  
of data transmitted from the PBX to a telephone, patient  
station, staff station or nurse control station is shown in  
Fig. 28. Return telephone voice and data information, e.g.,  
data to notify a called party who called, is generated in  
10 the PBX and is formatted into an 8 bit PBX data frame of  
approximately 8 ms. in length (i.e., 1 ms/bit). Two of the  
eight bits are designated as auxiliary. A sync frame is  
then added into each bit portion of the PBX data frame and  
the resultant signal is conditioned for PCM transmission to  
15 a station, e.g., either nurse control station 2414, patient  
station 2415 and/or staff station 2418.

Referring again to Fig. 25, the PCM signal  
received at a station from PBX 2430 is processed through a  
waveshaper and conditioner 4650. The waveshaper and  
20 conditioner 4650 converts the received signals from the PCM  
format to a serial digital format, recovers the  
synchronization clock to sync the timing via phase-locked  
loop 4670, and recaptures the telephone voice and data  
information. Data retrieved by the receiver waveshaping and  
25 conditioning 4650 is transferred to serial-to-parallel  
converter 4660 which converts the data from a serial format  
to a parallel format for interaction with microprocessor  
3512 and PCM CODEC 4630. PCM CODEC 4630 decodes the digital  
voice information for subsequent transmission of analog  
30 voice information to control unit 3210 for broadcast through  
speaker 4720, shown in Fig. 29.

According to the alternative embodiment, infrared  
sensitive photodiodes 4810 of receiver 4800 senses infrared



1 transmissions from an infrared transmitter and converts the  
infrared signals to electrical signals. Waveshaper and  
conditioner 4820 conditions and amplifies the electrical  
signals and FM receiver 4830 demodulates the data for the  
5 carrier signal and serially transfers the received data to  
an I/O port of microprocessor 3512. According to the  
alternative embodiment of the invention, the receiver 4800  
is capable of receiving infrared transmissions from portable  
transmitters at a distance of around 30 feet or greater from  
10 the station. Microprocessor 3512 receives the serial data  
from the FM receiver 4830 and extracts the transmitter ID  
information. The extracted information is reformatted and  
forwarded in an information packet to the PBX 2430 or the  
central processing unit 2412 for further processing and  
15 location determination.

Figs. 33-38 show the components of an exemplary  
wireless electromagnetic transmitter, such as an infrared  
transmitter, which may be incorporated into a badge unit  
5110, as well as various other known portable mediums, and a  
20 personnel or patient card 5200. The badge units are  
preferably adapted to be worn by staff members and/or  
patients within a health care facility using clip 5120, or  
adapted to be releasably attached to stationary or mobile  
devices or equipment using a suitable adhesive, identified  
25 as 5130, or like mediums such as VELCRO®. In instances  
where the transmitters are attached to devices or equipment,  
the transmitter permits tracking of such devices so as to  
permit staff members to easily determine the location of the  
device for retrieval and allow the badges to transmit  
30 information regarding the status of the equipment, such as  
on/off status. The badge unit includes a microcontroller  
4900 for controlling the operations of the badge and a  
transmitter 4910 for transmitting signals to a plurality of

1 receivers. The microcontroller 4900 is preferably a single  
integrated circuit chip which includes a processor and RAM  
and ROM memory.

Preferably, the transmitter is enclosed in a  
5 housing which is shaped and sized like an ordinary credit  
card or smaller. Figures 34-36 illustrate the side, top and  
bottom views, respectively, of the badge housing. The  
housing 5140, as shown, is approximately 3.8 inches in  
length, 2.27 inches in width and .39 inches in thickness.  
10 The housing 5140 includes a slot 5150 which is configured to  
receive personnel card 5200 shown in Figs. 37 and 38. Badge  
unit 5110 also includes electrical contacts 5160 which are  
connected to microcontroller 4900 of badge unit 5110 as  
shown in Fig. 33. Contacts 5160 are provided to engage  
15 corresponding contacts 5220 on the personnel card 5200 for  
data communications therebetween, as will be described in  
more detail below. A more detailed description of the badge  
unit is described in commonly assigned U.S. Patent  
Application Serial No. 08/087,394, filed July 2, 1993 which  
20 is incorporated herein by reference.

The ROM memory may be of the programmable type and  
stores software programs for operating the badge. These  
programs include: programs for controlling the transmitter  
4910; for monitoring operational parameters; and for  
25 interfacing with external devices. The RAM memory includes  
a database for storing information including an  
identification code of the badge and operational parameters  
which are retrieved and monitored by the processor for  
operating the badge unit. The database may further include  
30 information regarding the person associated with the badge,  
e.g., medicine which the person is allergic to. The  
database may also include information relating to an

1 associated object, e.g., medical equipment and its operating parameters or data.

Functions associated with the processor include: logical and arithmetic operations and coordination of data transfer to and from the microcontroller 4900. In the preferred embodiment, the processor also performs a fail safe function which periodically transmits a message to the central processing unit 2412 via patient station 2416 and PBX 2430. The periodic message, e.g., a fail safe code, is provided to inform the central processing unit 2412 that the badge is operational. Thus, if the message is not received from the badge unit, the central processing unit 2412 determines that either the badge unit has malfunctioned or that the badge unit is not within the operational confines of the system of the present invention, e.g., a staff member has left the hospital environment. The identification code of the badge may be utilized as the fail safe code which is periodically transmitted.

A microcontroller such as the PIC®16C5X manufactured by Microchip Technology, Inc. is used in the preferred embodiment of the present invention. It is apparent to one skilled in the art that any microcontroller having equivalent performance characteristics and similar in size may also be used.

25 An edge connector 4920, shown in Fig. 36, facilitates interfacing to the components of the badge from an external device, such as diagnostic medical equipment (not shown). The edge connector 4920 preferably has four connections which include a "Bidirect I/O" connection to an input/output port of the microcontroller 4900 for bidirectional communication with the microcontroller 4900. Data can be written into or read out of the microcontroller memory by the external device ("the Base") through this

1 connection. The Base preferably includes processing,  
storage and interfacing capabilities for communicating with  
and transferring information between the Base and the badge.  
A standard serial interface protocol such as RS232 may be  
5 used for such communications. In instances where the badge  
unit is connected to a medical device, such as a heart  
monitor, connector 4920 is connected to the serial port of  
the heart monitor and status data, e.g., the heart rate of  
the patient being monitored, of the heart monitor is  
10 transferred to microcontroller 4900 and then transmitted via  
transmitter 4910 to the patient station receiver described  
above, or to an independent wireless receiver which will be  
described hereinbelow.

Another connection associated with edge connector  
15 4920 is an "In-Base" connection which is monitored by the  
microcontroller 4900. An active signal at the "In-Base"  
input indicates that the microcontroller is to relinquish  
control to the external device. The badge according to the  
present invention is powered by a battery, which preferably  
20 is made of lithium. Other battery designs such as NICAD  
(nickel cadmium) rechargeable type or solar cell may also be  
used. The charge battery LED indicator 4950 provides a  
visual indication of the charge status of the battery. The  
charge battery circuitry may also be connected to  
25 microcontroller 4900, as shown in Fig. 33, so that the  
microcontroller can transfer the battery charge status  
information to the patient station via transmitter 4910.  
Alternatively, microcontroller 4900 may include a software  
counter which counts the number of transmissions from  
30 transmitter 4910 to determine the battery charge status of  
the badge. After a predetermined number of transmissions,  
microcontroller 4900 transmits to the patient station the  
battery charge status information, e.g., the battery power

1 is low. Preferably, the predetermined number of  
transmissions is based on the average power used per  
transmission and the statistical life of the battery.

Another input of the edge connector 4920 may be  
5 used to recharge the battery. The fourth connection of the  
edge connector 4920 is a spare input/output. The badge  
includes a light sensitive LED 4930 for providing wireless  
means for inputting data to the microcontroller 4900 by  
serially strobing data with a light source into the  
10 microcontroller 4900.

An oscillator 4940 is connected to the  
microcontroller 4900 for providing an oscillation signal,  
which in turn generates a clock signal for clocking or  
timing purposes. In the preferred embodiment, the  
15 oscillator 4940 includes a resistor/capacitor combination  
for providing a clock which operates at a frequency of  
around 455 kilohertz. Due to variations in the tolerances  
of the resistor/capacitor combination, the clock rate for  
each badge unit will vary from one badge to another  
20 substantially around 455 kilohertz. The microcontroller  
4900 includes a prescaler for providing time and clock  
signals.

A mode select switch 4960, preferably a normally  
open pushbutton switch, facilitates manual communication to  
25 the microcontroller 4900 for functions such as mode select  
or transmission of a preselected message. Typically, the  
function selected is dependant upon the number and sequence  
of button pushes. Examples for the modes of operation  
include: "erase memory" for erasing the contents of the RAM  
30 memory; "turn-off transmitter" for disabling any  
transmission from the badge; "card reinsertion" for turning  
off the badge when the personnel card is removed until a  
card is reinserted; "ID code change" for changing the ID

1 code to a special preselected code to signal an abnormal  
condition; and "disable counters" mode, which overrides  
parameter operations for turning off or disabling the badge  
and maintains badge operations.

5 Badge units which are worn by patients or  
releasably affixed to a structure which is proximal to the  
patient as shown in Fig. 39, may include a patient select  
switch or member 4970 shown in Fig. 36 which facilitates  
10 patient control of the environmental facilities within the  
patient's room and the nurse call function. Preferably, the  
patient select switch is a normally open pushbutton switch  
which controls such environmental facilities or the nurse  
call function via transmitter 4910 of the patient station  
2416 and CPU 2412 utilizing the communication techniques  
15 described above. Such environmental facilities include, for  
example, the television 5310, radio, draperies, thermostat  
5320 or the room lighting. Selection and control of a  
particular environmental facility or the nurse control  
function is dependant upon the number and sequence of button  
20 pushes. Data transmissions between the badge unit and the  
patient station is similar to the infrared data  
transmissions described above.

In an alternative embodiment shown in Figs. 39 and  
40, the badge unit may interface with an independent  
25 wireless electromagnetic receiver, preferably infrared  
receiver 5330. In one embodiment, each wireless receiver is  
located within the patient room and connected to a  
controller 5370 which responds to control data received from  
receiver 5330 to control the environmental facilities. In  
30 another embodiment, each wireless receiver is connected to  
either the central processing unit 2412 through zone  
controller 2420 or to the PBX 2430. In this embodiment,  
central processing unit 2412 or PBX 2430 will respond to the

1 control data in a similar manner as controller 5370 and  
communications between the independent receiver and the  
central processing unit 2412 or the PBX 2430 is similar to  
the above described communications relating to receiver  
5 4800, shown in Figs. 23 and 25. As shown in Fig. 40,  
infrared light sensitive diode array 5340 receives infrared  
signals, preferably frequency modulated infrared signals,  
transmitted from badge units 5140 within approximately 30  
feet of the receiver. Waveshaping and amplifier network  
10 5350 conditions and amplifies the signals generated by the  
diode array 5340. FM receiver 5360 demodulates the control  
data from the carrier signal and serially transfers the  
received control data to controller 5370.

Referring to Fig. 40, each independent infrared  
15 receiver 5330 is connected to a controller 5370 having a  
processor, memory and stored programs. Controller 5370  
receives the serial data from FM receiver 5360 and extracts  
the badge control data, e.g., the number and sequence of  
button pushes of the patient select switch 4970. The  
20 extracted control data is processed by controller 5370 to  
determine which environmental facility is being selected and  
which control function is to be performed. Preferably, each  
environmental facility is assigned an identification code  
which is stored in the memory of the controller. In this  
25 configuration, when control data is received by the  
controller, the controller determines which identification  
code has been received to select the desired environmental  
facility. For example, if the controller determines that  
the television has been selected, the controller may then be  
30 instructed to turn the television on or off, to change the  
channel or to increase or decrease the volume. A more  
detailed description of the FM infrared receiver and its

1 operation is described in U.S. Patent No. 4,977,519 to J. Crimmins, which is incorporated by reference.

Referring to Fig. 41, an alternative embodiment of the patient room configuration of Fig. 39 is shown. In this  
5 embodiment, all devices which were connected by wires, e.g., the patient station 2416 and thermostat 5320 shown in Fig. 39, except the ceiling wireless receiver 5330, have been made wireless and portable. All functions performed by the devices within the room as shown in Fig. 39 are performed by  
10 the wireless units. The wiring installation of the system as shown in Fig. 41, simply requires the wiring installation of wireless receiver 5330 within each patient room, connecting the wireless receiver to a central computer, controller or to the PBX. Generally, previously wired  
15 devices for controlling the environment are replaced with a unit with an integral transmitter. For example, thermostat 5320 includes a wireless transmitter 5322. Thermostat 5320 measures the ambient temperature within the room and transmits the temperature data to receiver 5330 via  
20 transmitter 5322. In addition, the patient may control other environmental facilities within the room, e.g., a television, via badge 5140 as described above. As shown in Fig. 41, the thermostat 5320 and the badge 5140 are placed on a night stand within the room and proximal to the  
25 patient.

The functions of the patient station 2416 and pillow speaker 3210 may be performed by an enhanced badge unit having components as shown in Fig. 42. The enhanced badge unit includes voice and display communication controls  
30 for communicating information previously performed by the patient station 2416 and pillow speaker 3210. The enhanced badge unit includes all the operations previously described for the badge unit and further includes: a wireless



1 receiver, e.g., an infrared receiver 5410 for receiving  
information; a card reader 5420 for reading information  
stored in the personnel card; a voice circuit 5430 for  
receiving voice signals from speaker 5440 and for  
5 translating digital signals to audio signals received from  
microphone 5450; a keypad 5460 for keypad entry of data; a  
display 5470 for displaying information such as data entered  
from the keypad 5460 or data received from the receiver  
5410; and a membrane switch (not shown) for special  
10 designated functions such as an emergency call or sending a  
selected message. A more detailed description of the  
enhanced badge unit is described in U.S. Patent Application  
Serial No. 08/087,394, filed July 2, 1993 which is  
incorporated herein by reference.

15 An exemplary personnel or patient card 5200 is  
shown in Figs. 37 and 38 and operates in a manner similar to  
the personnel card shown and described in commonly assigned  
U.S. Patent Application Serial No. 07/924,101, filed August  
3, 1992 which is incorporated herein by reference. As  
20 shown, the personnel card is configured and dimensioned for  
insertion within the slot 5150 of the badge unit 5110, shown  
in Fig. 35. The front surface of the card may include a  
printed logo and other identification information.

The rear surface of the card includes an  
25 identifier circuit 5210 which interfaces with  
microcontroller 4900 of the badge unit to perform a lockout  
function. The identifier circuit includes a ROM which has a  
validation code stored therein and circuitry to read the  
validation code from the ROM and transfer the data to  
30 electrical contacts 5220. Such circuitry is known to those  
skilled in the art. Preferably, the identifier circuit is  
in the form of a single integrated circuit which is  
preferably dimensioned at approximately .25 inches square

1 and between about 0.002 of an inch and about 0.004 of an  
inch thick for mounting on the rear surface of the card.  
Electrical contacts 5220 of card 5200 are connected to  
2 identifier circuit 5210 so that when the card is inserted  
5 into the badge unit slot 5150, contacts 5220 are engaged  
with contacts 5160 of the badge unit. The identifier  
circuit transfers a validation code to the microcontroller  
4900 of the badge unit. Microcontroller 4900 then  
determines whether the card validation code is valid so as  
10 to activate the badge unit circuitry and permit the person  
in possession of the card to use the badge unit. If the  
microcontroller 4900 determines that the validation code is  
improper or that no validation code is received, then  
microcontroller 4900 will deactivate the badge unit  
15 circuitry and prevent the person in possession of the card  
from using the badge unit.

Fig. 29 is a circuit block diagram of the patient  
control unit 3210. Patient control unit 3210 includes  
telephone keypad 4710, speaker 4720 and microphone 4730  
20 which are connected to PCM CODEC 4630 in telephone circuit  
4610 and provide telephone voice and data communications  
between the patient stations and PBX 2430. The PCM CODEX  
4630 may include a DTMF decoder for decoding DTMF tones from  
the telephone keypad 4710.

25 Fig. 30 is a circuit block diagram of the nurse  
control station 2414 which includes PBX interface or  
telephone circuitry 4610 connected to microcontroller 3324,  
keys 3328, speaker 3338, handset 3340 and microphone 3342 to  
provide telephone communications between the nurse control  
30 station and the other stations and/or to provide external  
telephone communications. Staff stations 2418 include the  
same components as shown in Figure 25 for the patient  
stations 2416, except in the staff stations, the speaker

- 1 4018, keypad 4019 and microphone 4020 for providing  
telephone communications between the staff station and the  
other stations and/or to provide external telephone  
communications are integrated within the staff station.
- 5 Communications between the staff stations 2418 and the PBX  
2430 are same as described for the patient stations 2416 and  
are shown in Figures 26 to 28.

STATIONS USING A PBX FOR TELEPHONE  
AND SYSTEM DATA COMMUNICATIONS

- 10 Another alternative embodiment for the system  
configuration is shown in Fig. 31. In this embodiment  
private-branch exchange (PBX) 2430 is connected to central  
computer 5010, to nurse control stations 2414, patient  
15 stations 2416 and staff stations 2418 and is provided to  
facilitate system data communications as well as staff-to-  
staff, staff-to-patient and/or external telephone  
communications for the hospital environment.

- Central computer 5010 provides standard control of  
20 PBX 2430 such as processing telephone data received by the  
PBX and providing the PBX with the connection information to  
interconnect particular stations for voice communications.  
For example, if a staff member attending a nurse control  
station calls a patient station where another staff member  
25 is attending to a patient, central processing unit 5010  
processes the telephone data, e.g., patient station identity  
of the called party, and provides the PBX with the necessary  
information to interconnect the two stations. In addition,  
central processing unit 5010 is utilized to process the  
30 system data to perform system functions, e.g., the call  
priority, nurse follow, voice paging and room monitoring  
functions as previously described. The system data is

1 preferably formatted in the following protocol by  
microprocessor 3512:

ST; SYSTEM DATA; SP

5

where the ST field is a one byte start message field. The  
SYSTEM DATA field is preferably between one and 16 bytes in  
length and provides the PBX with the system data, e.g, code  
blue data. The SP field is a one byte stop message field.

10 According to an alternate embodiment, the PBX 2430  
includes capabilities to process the telephone data and  
automatically connect the calling stations with the called  
stations for telephone and/or data communications  
independent of central processing unit 5010.

15 The PCM signal received at a station from PBX 2430  
is then processed through a waveshaping and conditioning  
network 4650, shown in Fig. 25. Network 4650 converts the  
received signal from the PCM format to a serial digital  
format, recovers the synchronization clock to sync the  
20 timing via phase-locked loop 4670, and recaptures the  
telephone voice and data information and the system data.  
System Data is retrieved by the receiver waveshaping and  
conditioning network 4650 using an alternate mark inversion  
(AMI) conversion technique. The AMI conversion method  
25 changes the level of the output signal for each positive  
crossing of the zero line by the input signal, as shown in  
Fig. 32.

It will be understood that various modifications  
can be made to the embodiments of the present invention  
30 herein disclosed without departing from the spirit and scope  
thereof. For example, various system configurations are  
contemplated, as well as various types of protocols utilized  
to communicate between the numerous stations utilized within

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1 the system of the present invention. In addition, numerous  
functions aside from those described herein may be  
programmed and performed in the system of the present  
invention. Therefore, the above description should not be  
5 construed as limiting the invention but merely as  
exemplifications of preferred embodiments thereof. Those  
skilled in the art will envision other modifications within  
the scope and spirit of the present invention as defined by  
the claims appended hereto.

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1 WHAT IS CLAIMED IS:

1. A patient care and communication system which comprises:

5 a central station having means for facilitating visual and data communications relating to patient care; and  
a plurality of remote stations linked to said central station and having a processor for facilitating visual and data communications relating to patient care and having a display for displaying said visual communications;  
10 and

a private branch exchange connected to a telephone exchange and to a plurality of telephones for facilitating telephone communication between said telephones and said exchange;

15 wherein said central station facilitates said visual and data communications between said plurality of remote stations, and includes means for determining which of said plurality of remote stations are transmitting said visual and data communications and which of said plurality  
20 of remote stations are to receive said visual and data communications, and includes means for establishing a communication link between said transmitting stations and said receiving stations;

wherein each of said plurality of remote stations  
25 includes telephone circuitry connected to said private-branch exchange for telephone communications therebetween.

2. The patient care and communication system according to claim 1, wherein said plurality of remote stations includes control stations and patient stations.

30 3. The patient care and communication system according to claim 2, wherein said plurality of remote stations includes staff stations.

1           4. The patient care and communication system  
according to claim 1, wherein at least a portion of said  
plurality of remote stations are configured and adapted for  
association in a group network such that predefined visual  
5 and data signal communications are transmitted to each  
station in the group by said central station and audio  
communications are transmitted by said private-branch  
exchange.

          5. The patient care and communication system  
10 according to claim 3, wherein said central station includes  
means for directing said private-branch exchange to  
establish audio communication between a predetermined number  
of said control stations and a predetermined number of said  
patient stations and a predetermined number of said staff  
15 stations.

          6. The patient care and communication system  
according to claim 1 further comprising zone controller  
means for interfacing said central station to said  
transmitting and receiving stations for data communications  
20 therebetween.

          7. The patient care and communication system  
according to claim 2, wherein said patient stations include  
patient control means connected thereto, said patient  
control means including a keypad, a speaker and a microphone  
25 for telephone communications.

          8. The patient care and communication system  
according to claim 2, wherein said central station includes  
means for directing said private-exchange to activate audio  
communications between said control stations and a  
30 predetermined number of said patient stations to facilitate  
audio monitoring of patient rooms from said control  
stations.

1           9. The patient care and communication system  
according to claim 2, wherein said control stations comprise  
a microprocessor for controlling the operation of said  
control stations and said PBX interface means, memory means  
5 connected to said microprocessor for storing programs and  
data, peripheral interface means for interfacing said  
microprocessor to peripheral equipment so as to facilitate  
the input and output of said visual and data signal  
communications.

10           10. The patient care and communication system  
according to claim 2 further comprising locating means  
linked to said central station for determining the location  
of staff members and transferring said staff location data  
to said central station so as to facilitate visual and data  
15 communications between said control stations and said  
patient stations provided at the detected location of the  
staff members, said central station directing said private-  
branch exchange to activate audio communication between said  
control stations and said patient station at said detected  
20 location.

          11. The patient care and communication system  
according to claim 1, wherein said plurality of remote  
stations include receivers adapted to receive and convert  
infrared transmissions to electrical signals.

25           12. The patient care and communication system  
according to claim 11 further comprising a portable  
transmitter adapted to be releasably attached to an object,  
said transmitter being adapted for infrared transmission.

          13. The patient care and communication system  
30 according to claim 12 wherein said portable transmitter  
includes a housing and a processor within said housing.



1           14. The patient care and communication system  
according to claim 13 wherein said portable transmitter  
includes a patient select member connected to said processor  
to permit persons within a room to control environmental  
5 facilities within the room.

          15. The patient care and communication system  
according to claim 12 wherein said portable transmitter  
transmits data substantially periodically to said remote  
stations so as to provide said central station with  
10 information reflecting the status of said portable  
transmitter.

          16. The patient care and communication system  
according to claim 15, wherein said status information  
includes a message that the portable transmitter is  
15 operational.

          17. The patient care and communication system  
according to claim 15, wherein said status information  
includes battery charge data.

          18. The patient care and communication system  
20 according to claim 13, wherein said housing includes a slot  
configured to receive a personnel card, said housing having  
at least one electrical contact connected to said processor  
and said personnel card having at least one electrical  
contact engagable with said at least one housing contact to  
25 permit the transmission of data between said personnel card  
and said processor.

          19. The patient care and communication system  
according to claim 18, wherein said personnel card includes  
an identifier circuit which transfers validation data to  
30 said processor, wherein said processor determines if the  
validation code is valid so as to activate said transmitter  
and permit the person in possession of said card to use said  
portable transmitter.

1           20. A patient care and communication system which  
comprises:

          a central station having a processor for  
facilitating visual and data signal communications relating  
5 to patient care;

          a private-branch exchange coupled to said central  
station;

          at least one patient station having a processor  
which facilitates visual and data signal communications  
10 relating to patient care, a display to display text received  
from said data signal communications and telephone circuitry  
coupled to said private-branch exchange for telephone  
communications between stations; and

          at least one control station having a processor  
15 which facilitates visual and data signal communications  
relating to patient care, a display for displaying text  
received from said data signal communications and a PBX  
interface coupled to said private-branch exchange for  
telephone communications between stations;

20           wherein said processor of said central station  
facilitates said visual and data signal communications  
between said at least one patient station, and said at least  
one control station, and determines which of said at least  
one patient station or said at least one control station is  
25 transmitting said visual and data signals and which of said  
stations are to receive said visual and data signals, and  
establishes a communication link between said transmitting  
stations and said receiving stations.

          21. The patient care and communication system  
30 according to claim 20 further comprising at least one staff  
station having a processor which facilitates visual and data  
signal communications relating to patient care, a display  
for displaying text received from said data signal

1 communications and telephone circuitry coupled to said  
private-branch exchange for telephone communication between  
stations.

22. A patient care and communication system which  
5 comprises:

a central station having means for facilitating  
visual and data communications relating to patient care; and  
a plurality of remote stations linked to said  
central station and having processing means for facilitating  
10 visual and data communications relating to patient care and  
having display means for displaying said visual  
communications, each of said plurality of remote stations  
includes a receiver adapted to receive transmitted signals  
for data communication to said central station;

15 a private branch exchange connected to a telephone  
exchange and to a plurality of telephones for facilitating  
telephone communication between said telephones and said  
exchange;

wherein each of said plurality of remote stations  
20 includes telephone circuitry connected to said private-  
branch exchange for telephone communications therebetween;  
and

at least one portable transmitter adapted to be  
worn by personnel in a facility, said transmitter being  
25 adapted for transmission of signals including the identity  
of the personnel;

wherein said central station includes means for  
determining the identity and location of the personnel  
associated with said at least one transmitter in response to  
30 said transmitted signals.

1           23. The patient care and communication system  
according to claim 22, wherein said central station  
facilitates said visual and data communications, including  
said received transmitted signals, between said plurality of  
5 remote stations, and includes means for determining which of  
said plurality of remote stations are transmitting said  
visual and data communications and for establishing a  
communication link between a transmitting remote station and  
a remote station in the determined location of the person.

10           24. A method of providing patient care and  
communication between patient rooms and nurse stations in a  
health care facility comprising:

                  connecting a plurality of remote stations to a  
central processor so as to facilitate visual and data  
15 communications therebetween, said plurality of remote  
stations having processing means for facilitating said  
visual and data communications and having display means for  
displaying said visual communications, and said central  
processor having means for determining which of said  
20 plurality of remote stations are transmitting said visual  
and data communications and which of said plurality of  
remote stations are to receive said visual and data  
communications, and having means for establishing a  
communication link between said transmitting stations and  
25 said receiving stations;

                  connecting said plurality of remote stations and  
said central processor to a private-branch exchange for  
audio communications between said stations.

                  positioning at least one of said plurality of  
30 remote stations in each patient room located within the  
health care facility;

1           positioning at least one of said plurality of  
remote stations in each nurse station of said health care  
facility;

          attending said remote station in each nurse  
5 station to receive said visual and data signals from said  
central processor and audio signals from said private-branch  
exchange; and

          responding to said audio, visual and data signals.

          25. Apparatus for remotely controlling  
10 environmental facilities within a room of a health care  
facility, which comprises:

          a wireless receiver positioned within said room  
having environmental facilities therewithin;

          a wireless transmitter located within said room,  
15 said wireless transmitter having a housing, a processor  
within said housing and a patient select member connected to  
said processor, such that activation of said patient select  
member causes said wireless transmitter to transmit control  
data to said wireless receiver; and

20           a controller connected to said wireless receiver  
and said environmental facilities, said controller being  
configured to receive said control data from said wireless  
receiver and to control said environmental facilities in  
response to said control data.

25           26. The apparatus according to claim 25, wherein  
said environmental facilities include a thermostat.

          27. The apparatus according to claim 26, wherein  
said thermostat is portable and includes a wireless  
transmitter to transmit temperature data to said controller  
30 to permit the controller to regulate ambient temperature  
within said room.

1           28. The apparatus according to claim 25, wherein  
said wireless receiver comprises an infrared receiver and  
said wireless transmitter comprises an infrared transmitter.

5           29. The apparatus according to claim 25, wherein  
said wireless transmitter includes a connector which  
facilitates connection of said wireless transmitter to  
medical equipment, reception of status data from said  
medical equipment and transmission of said status data to  
said wireless receiver.

10          30. A method for controlling environmental  
facilities within rooms of a health care facility,  
comprising:

          positioning a wireless receiver within rooms  
having environmental facilities therewithin;

15          positioning a portable wireless transmitter within  
the rooms;

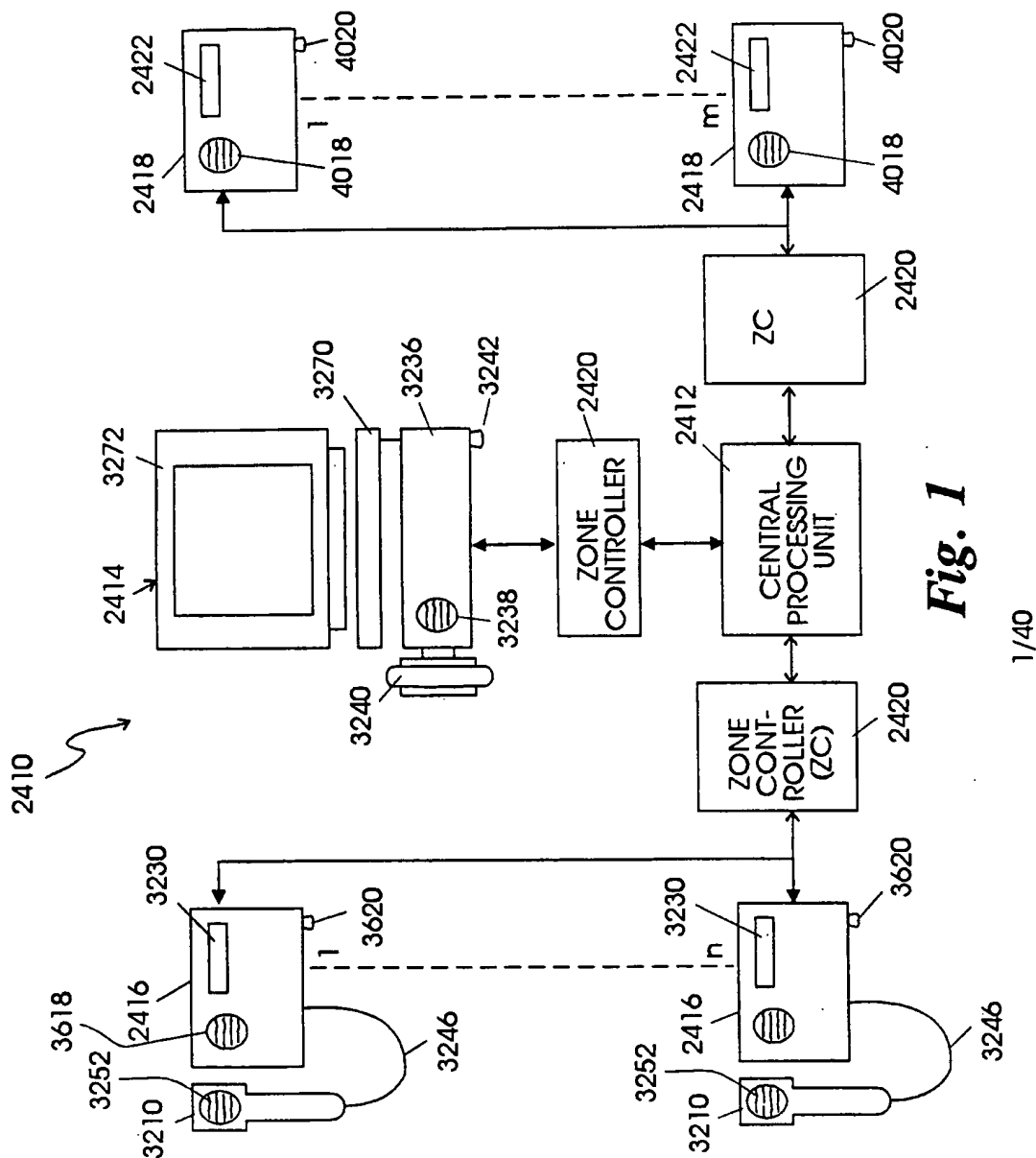
          connecting said wireless receiver and said  
environmental facilities to a controller, said controller  
being configured to receive control data from said wireless  
20 receiver and to control said environmental facilities in  
response to said control data; and

          activating said wireless transmitter to transmit  
said control data.

25

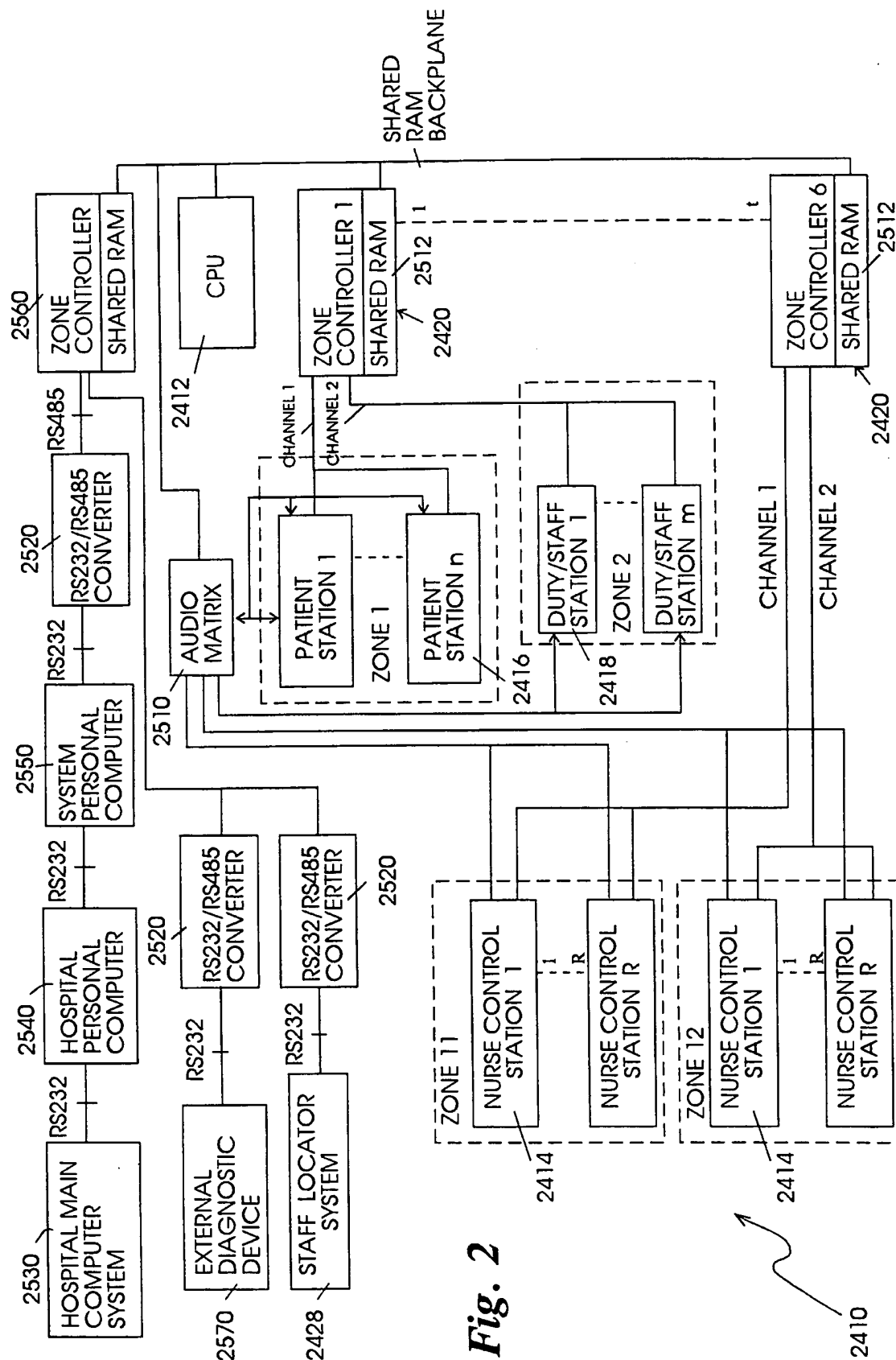
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**Fig. 1**

1/40



**Fig. 2**



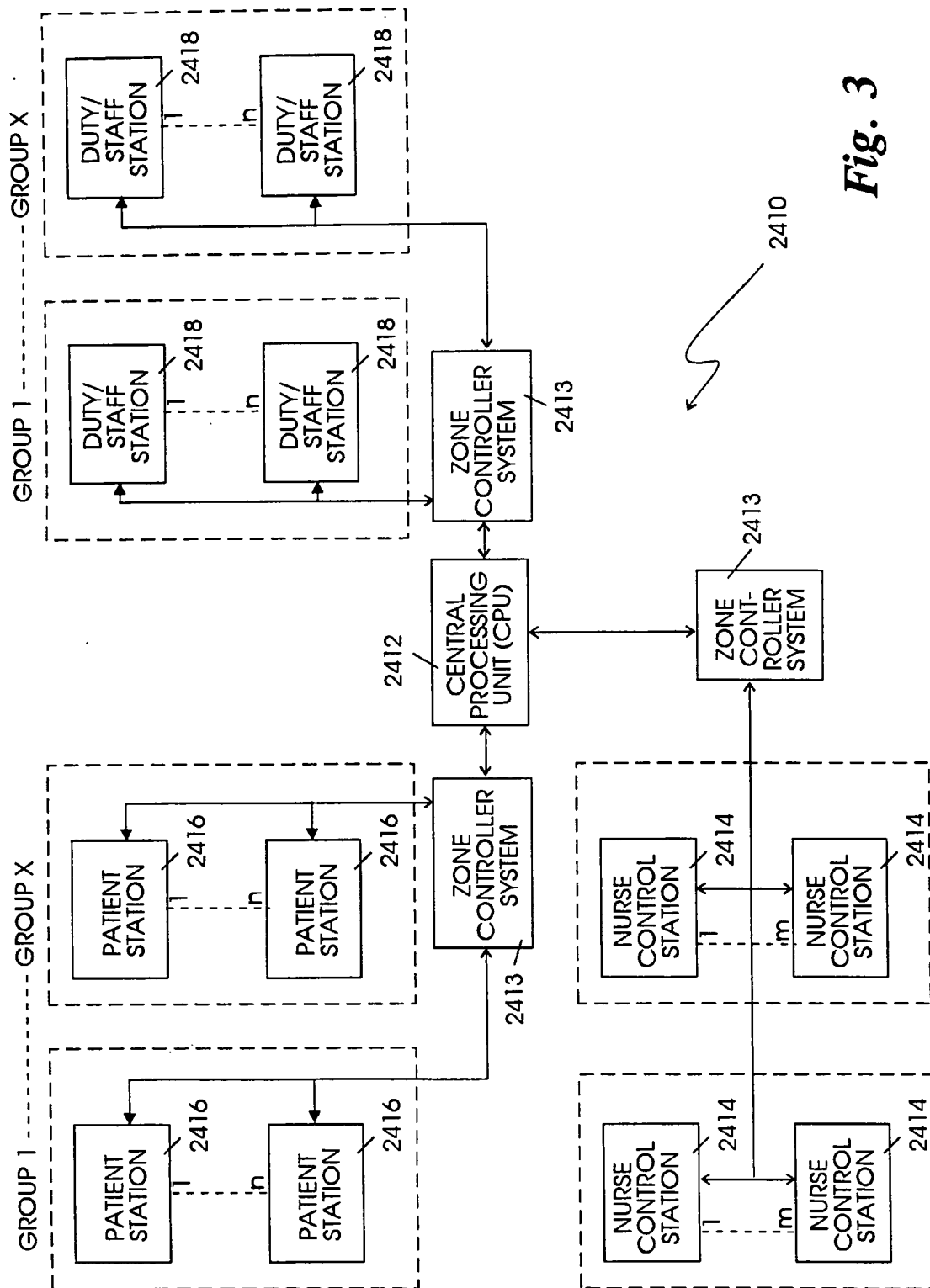
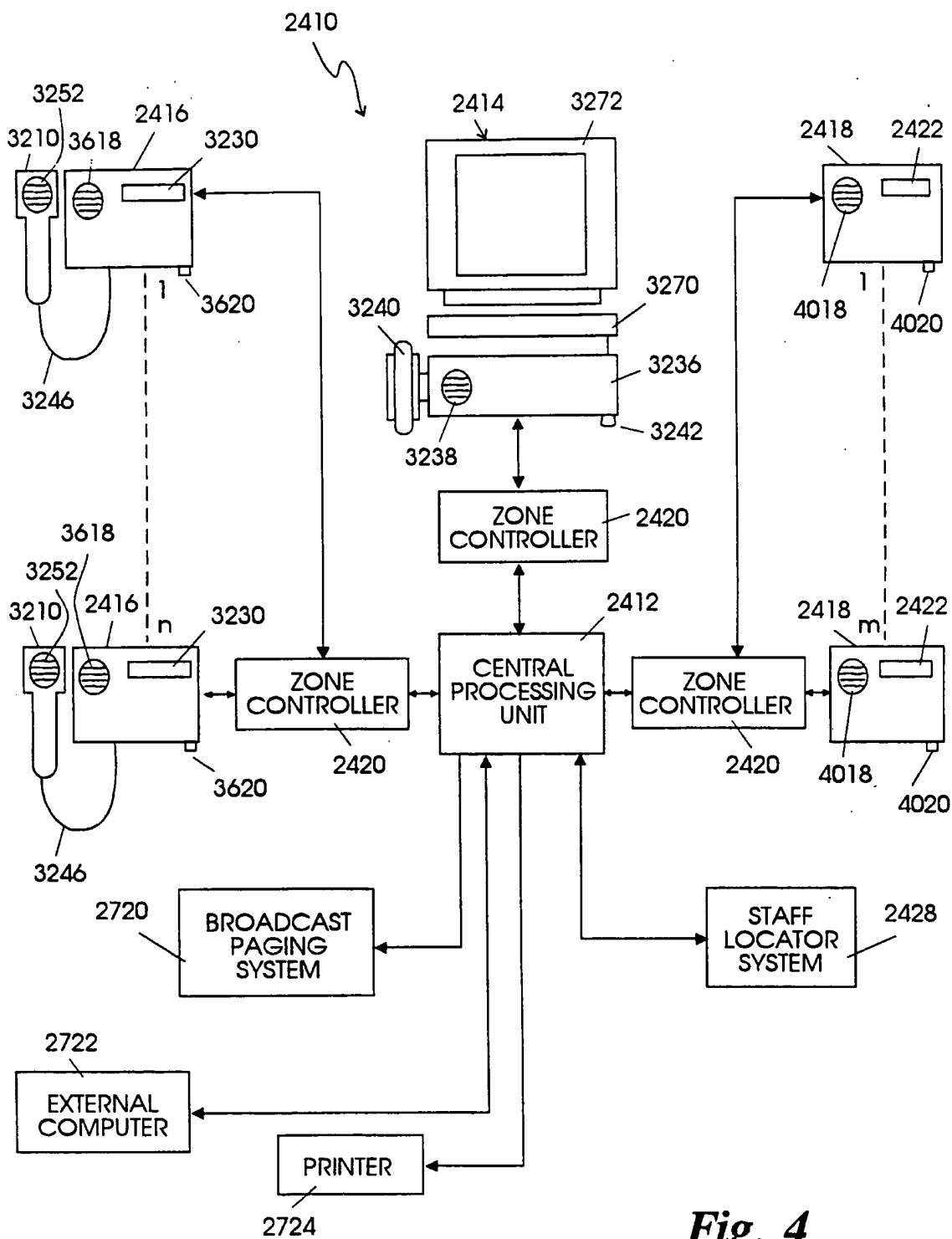
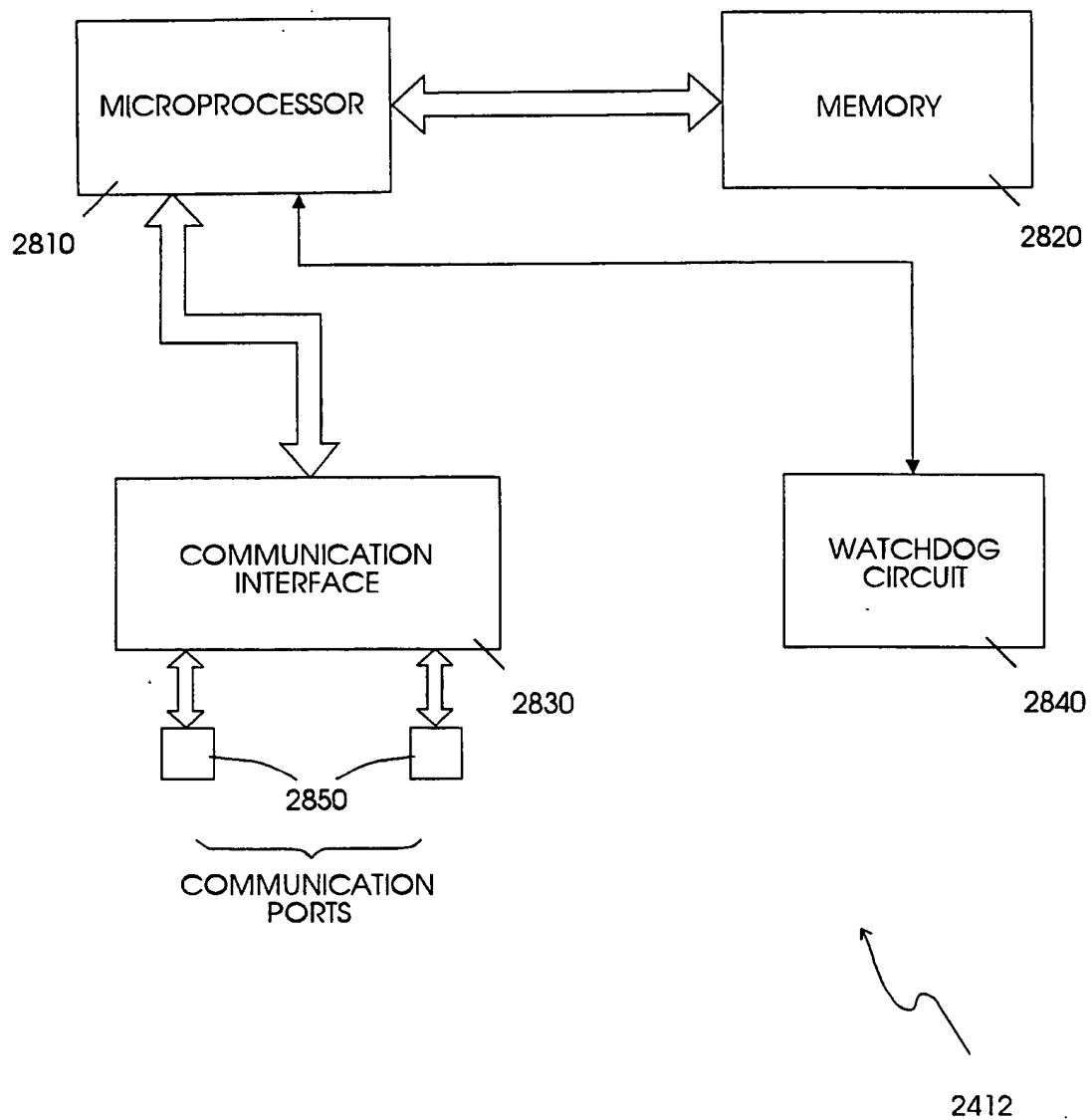
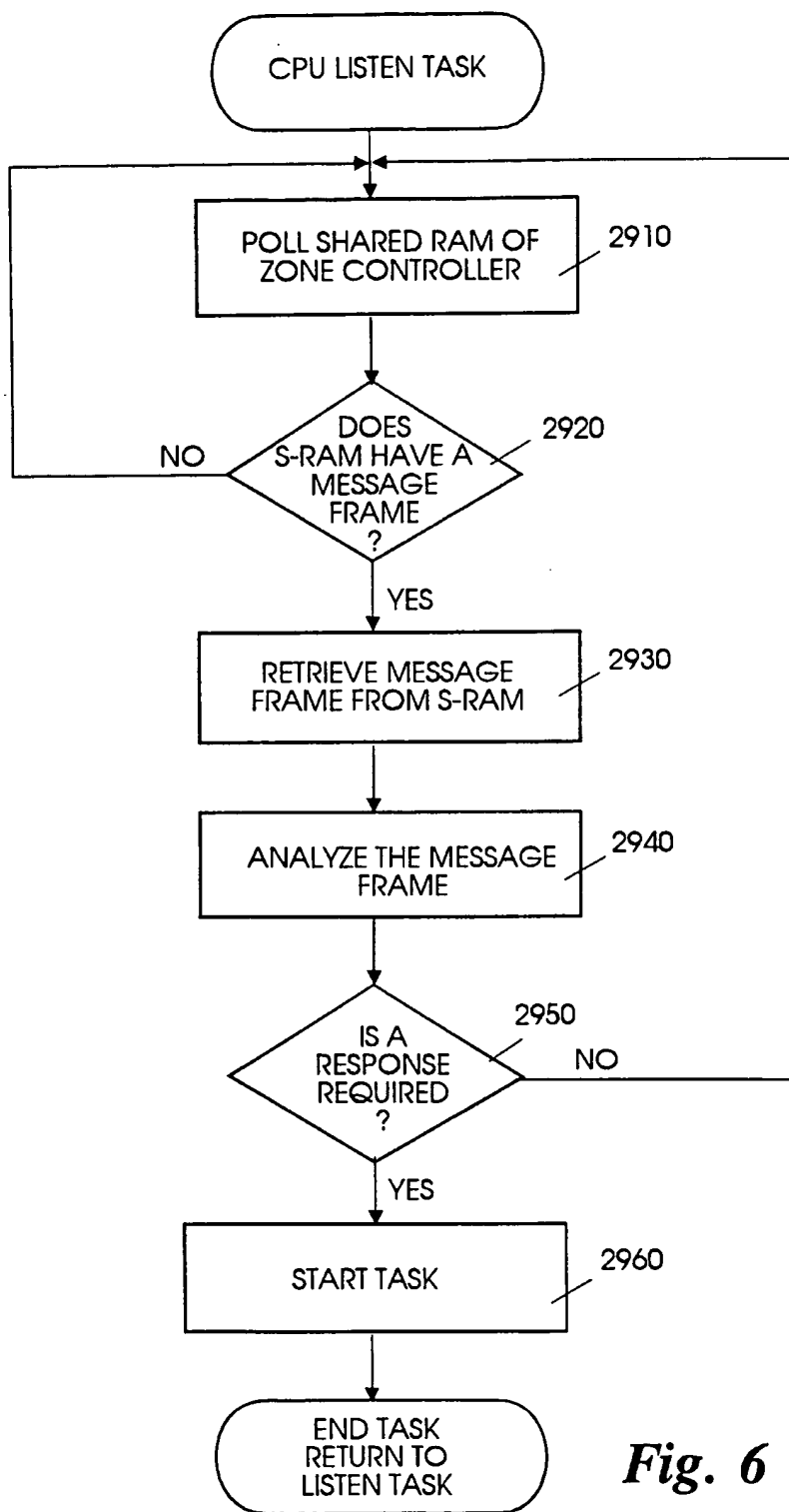


Fig. 3

**Fig. 4**

*Fig. 5*

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**Fig. 6**

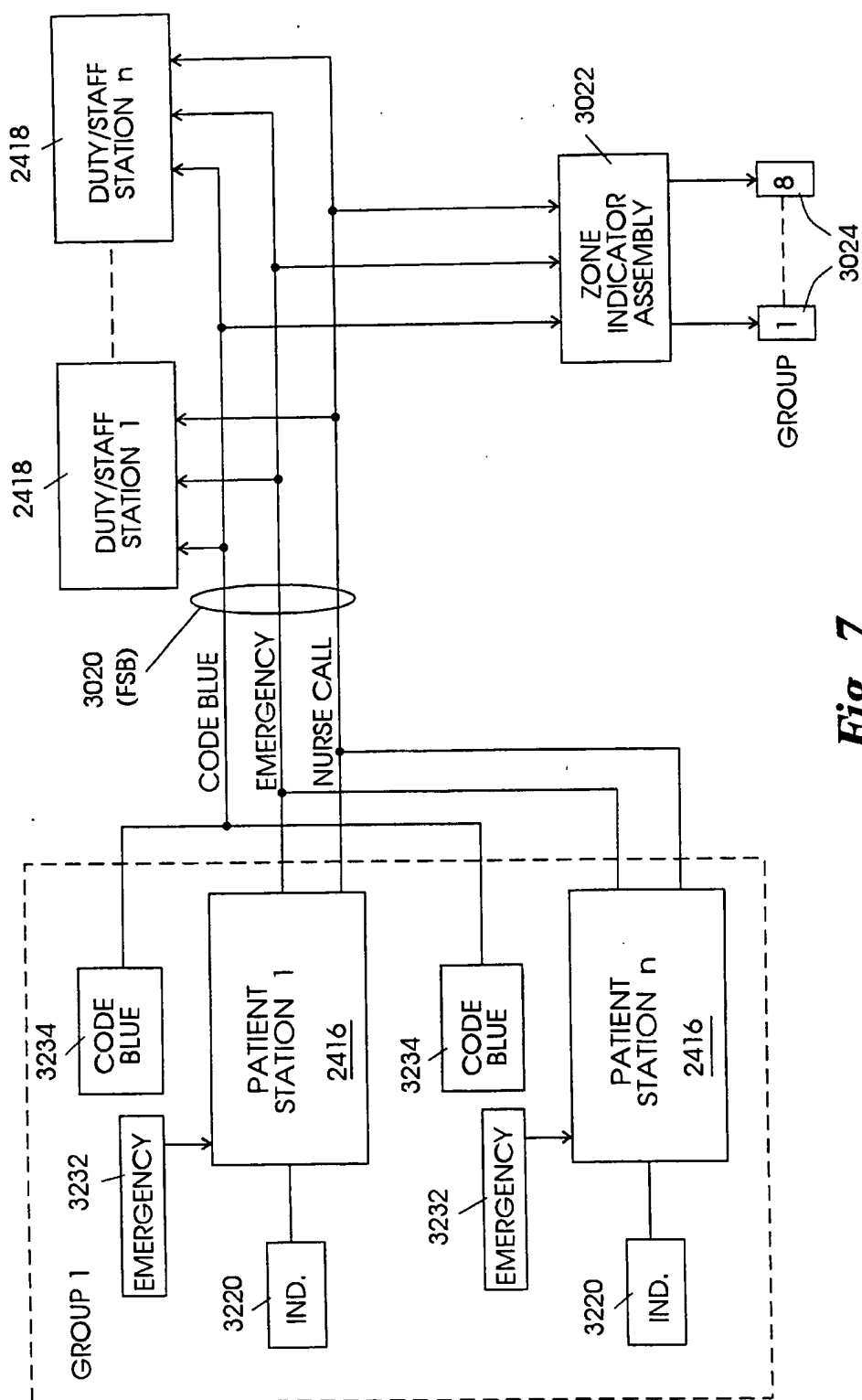
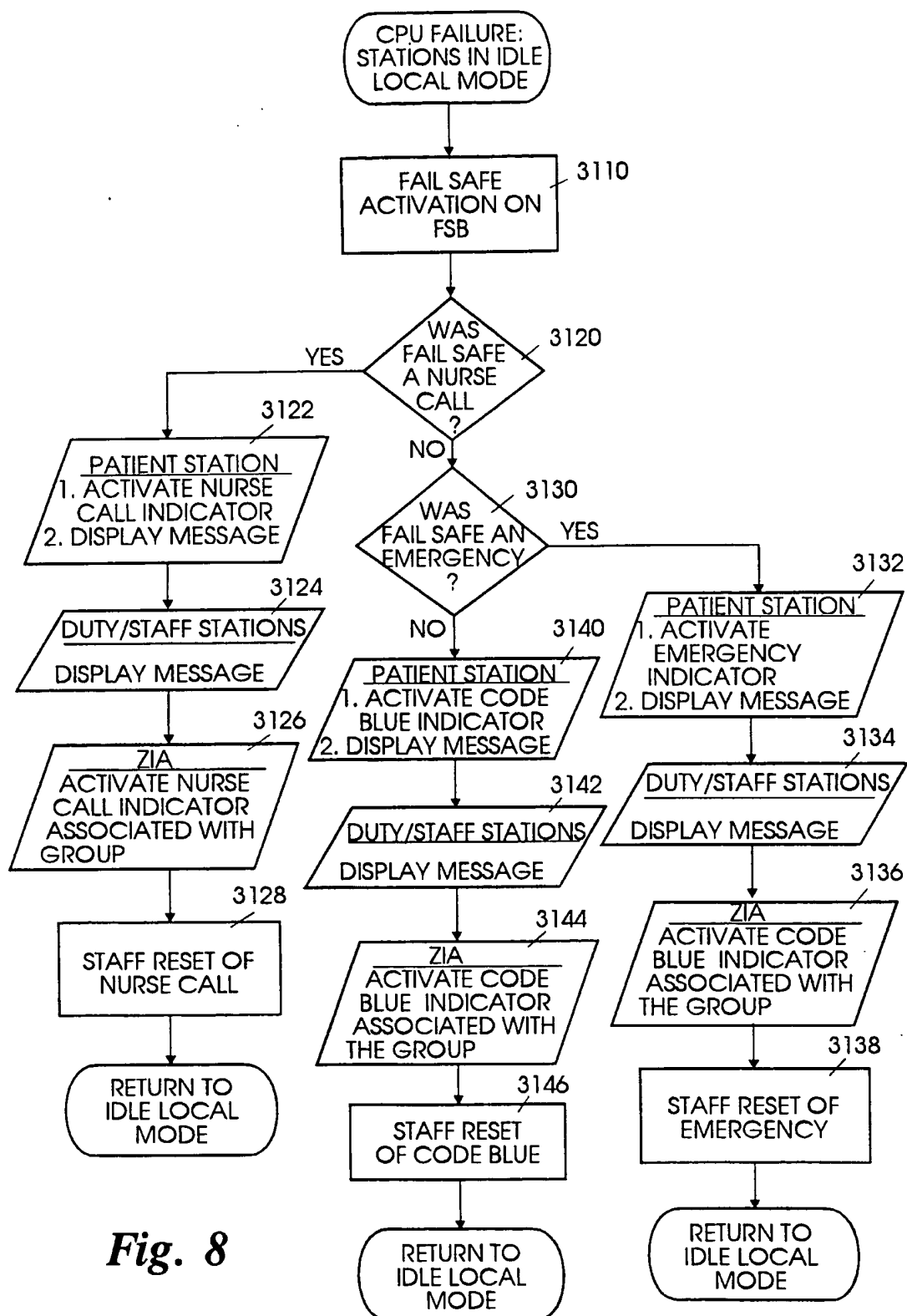
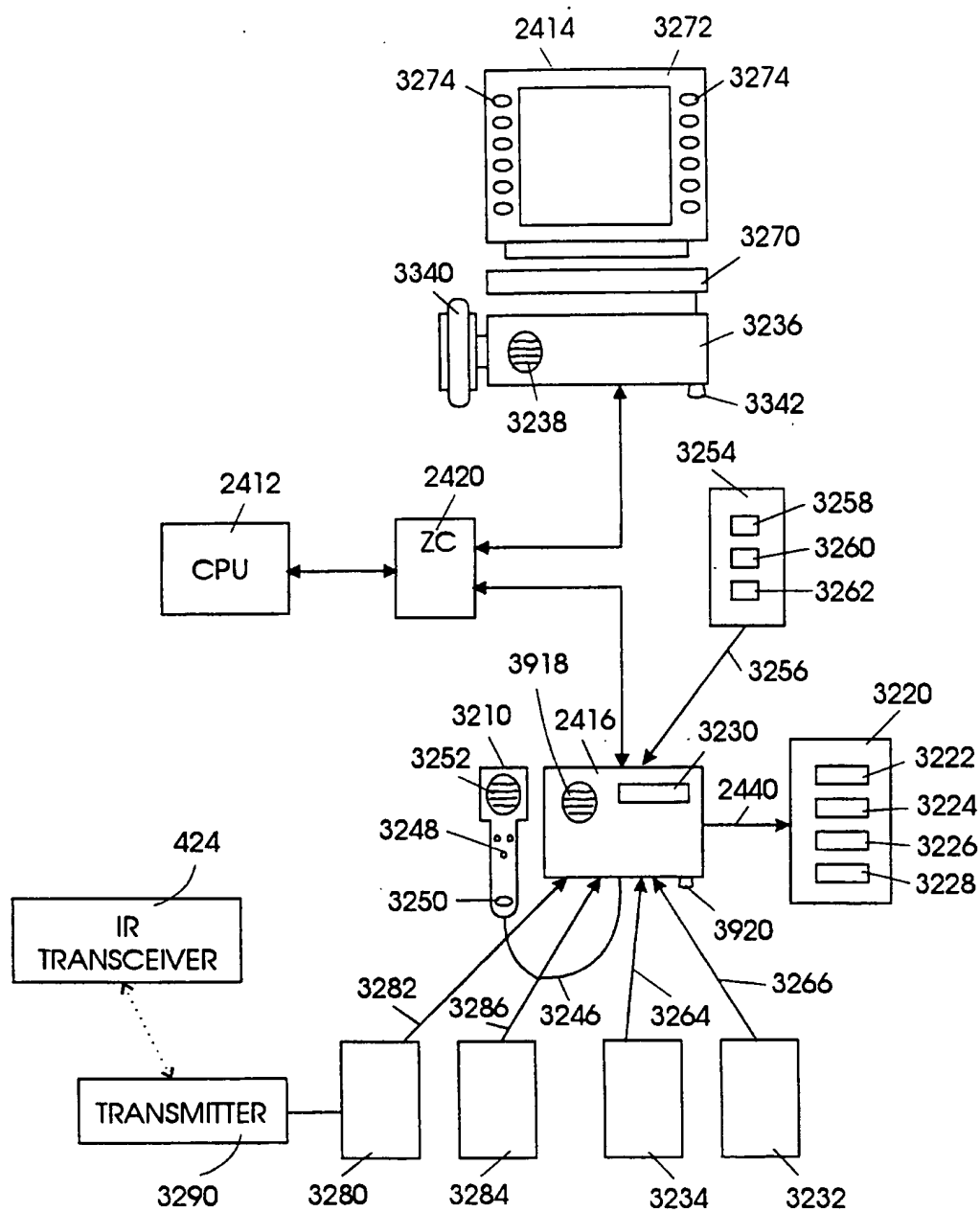


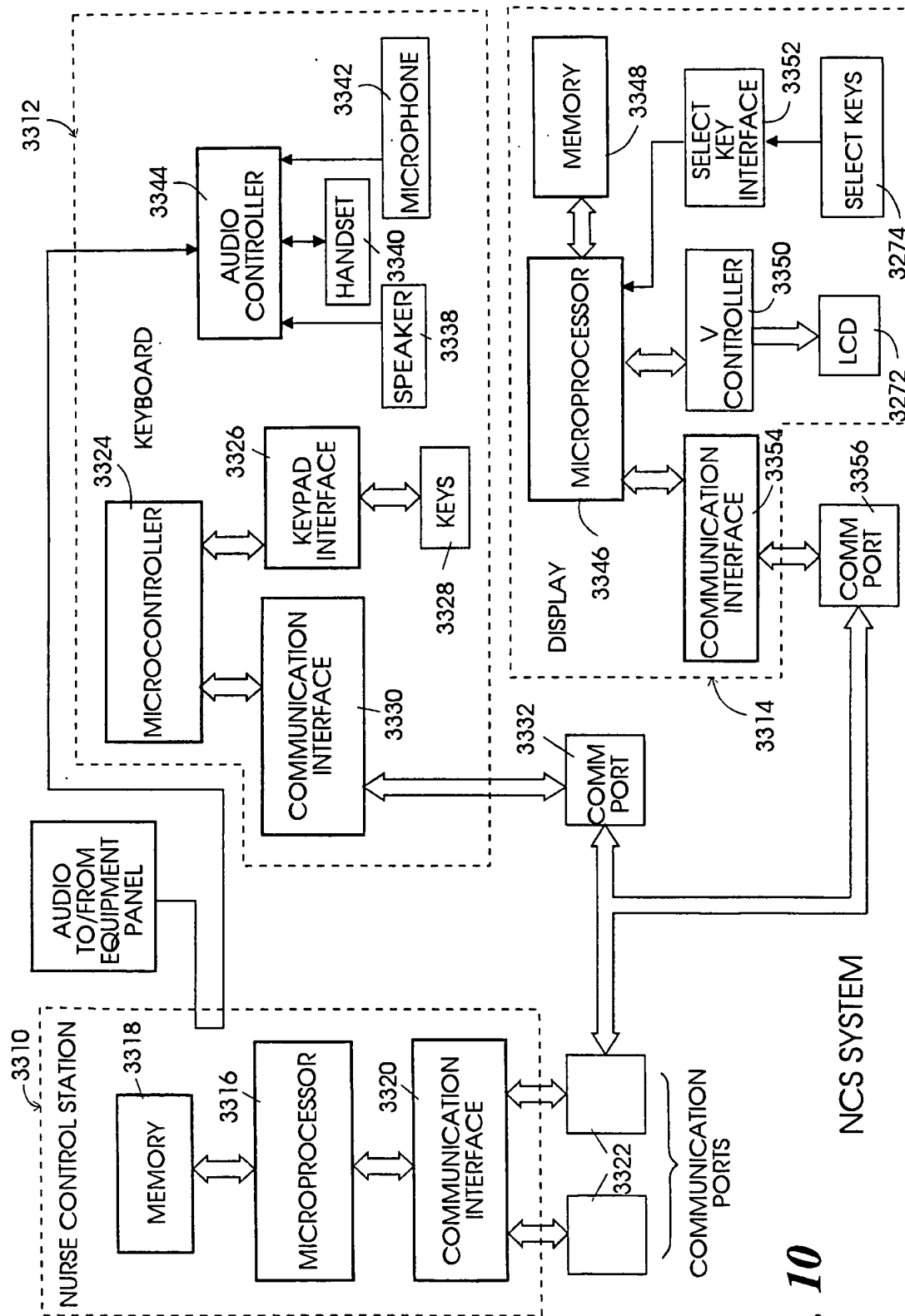
Fig. 7

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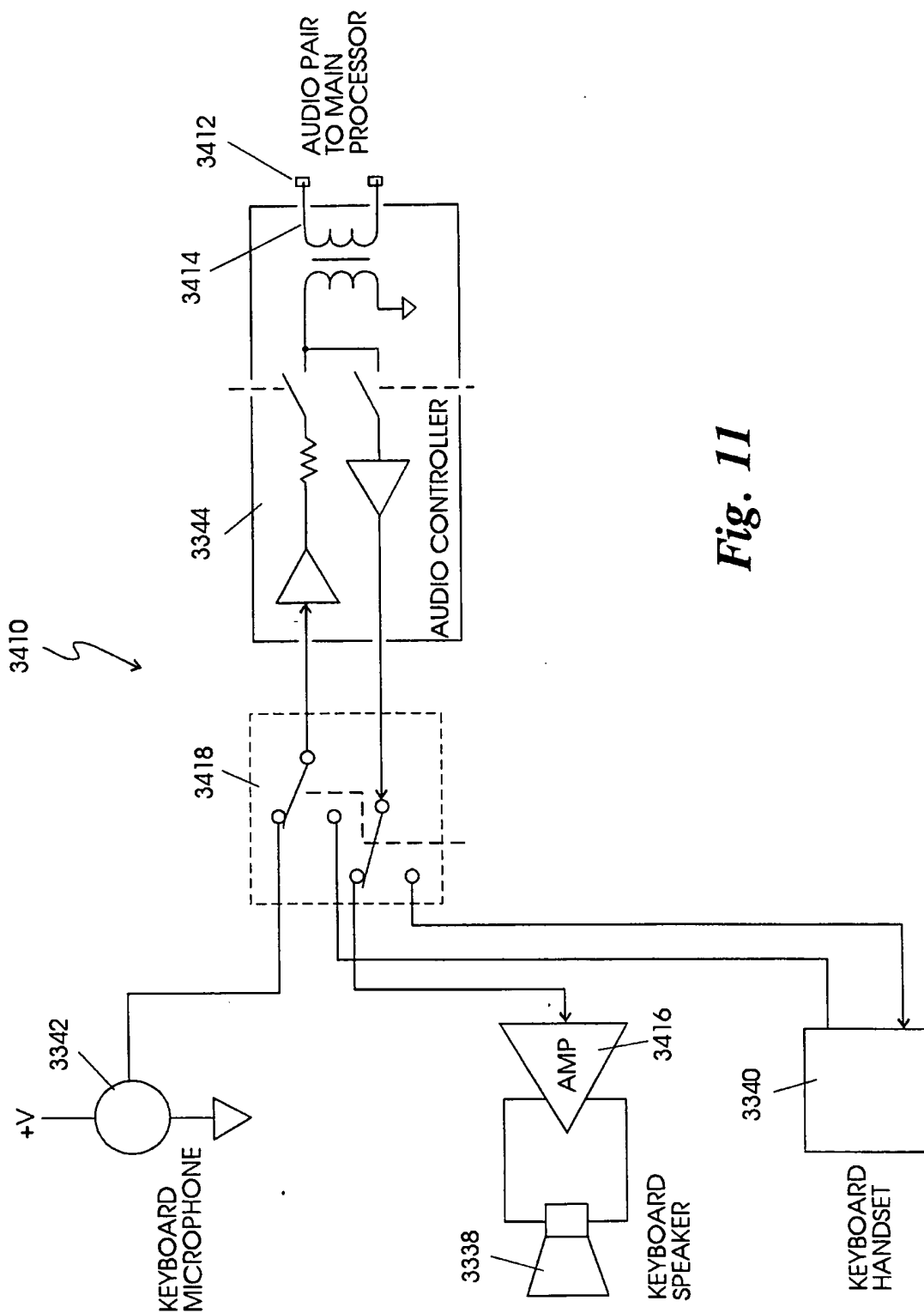
**Fig. 8**

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**Fig. 9**

**Fig. 10**





**Fig. 11**

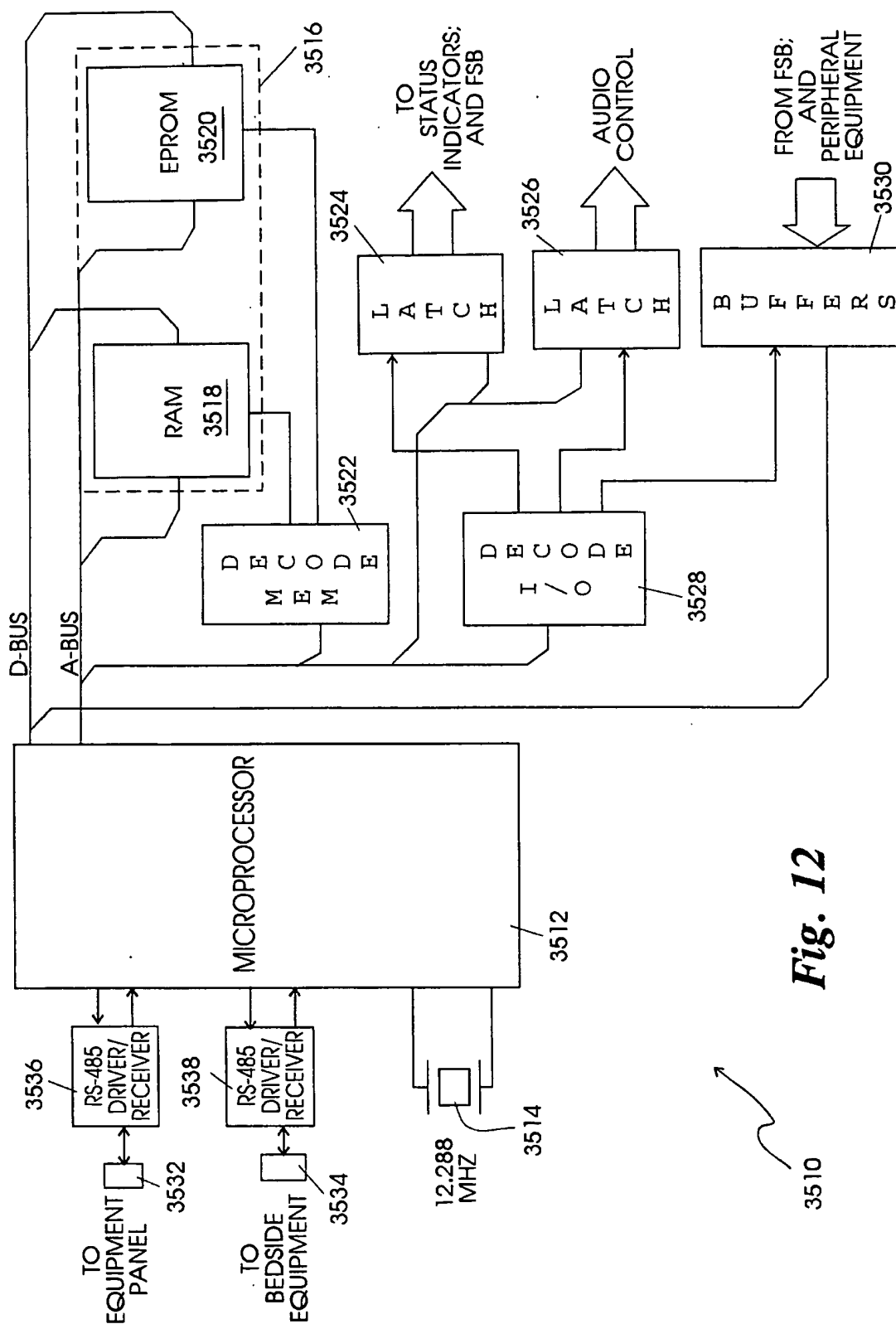
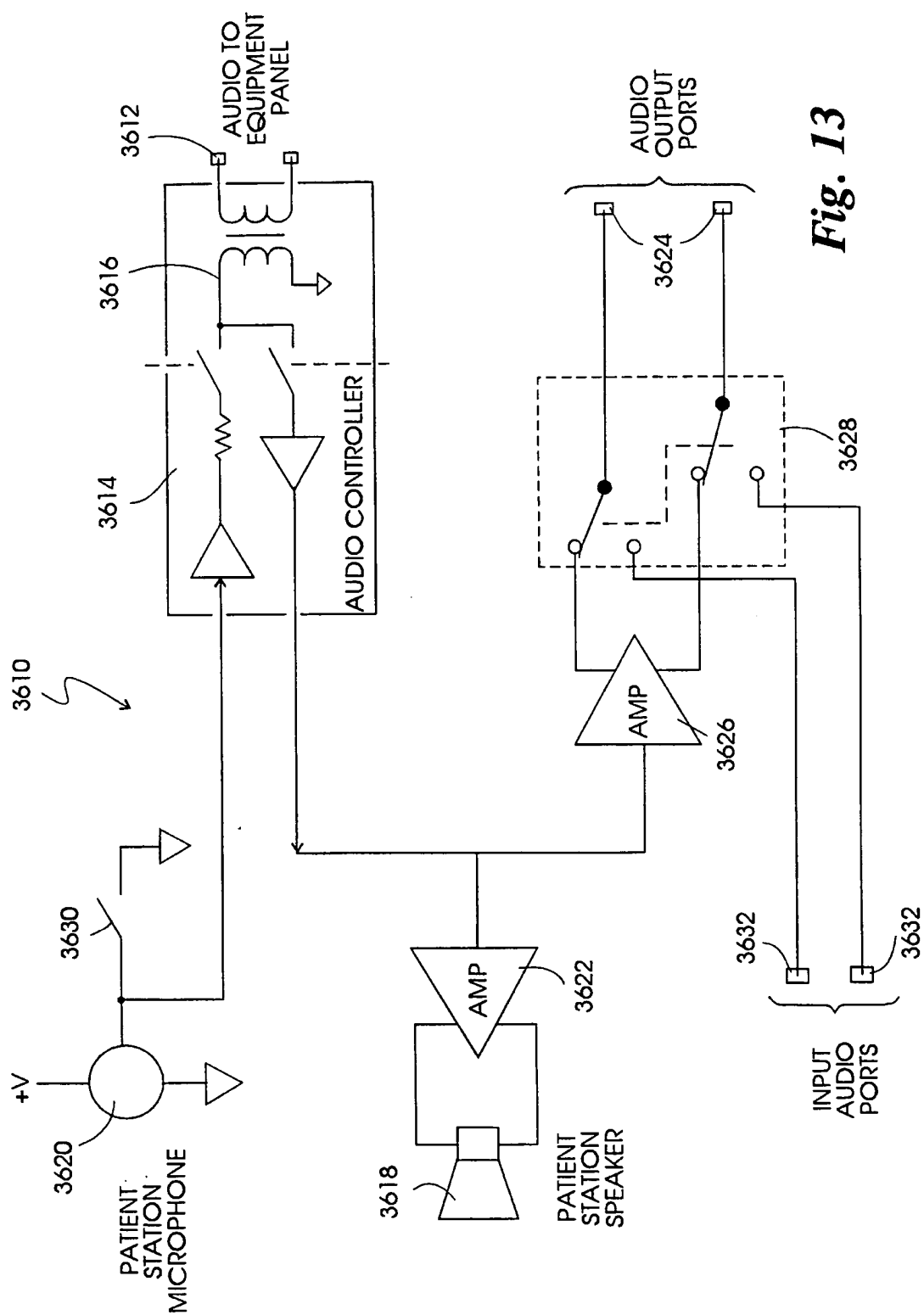
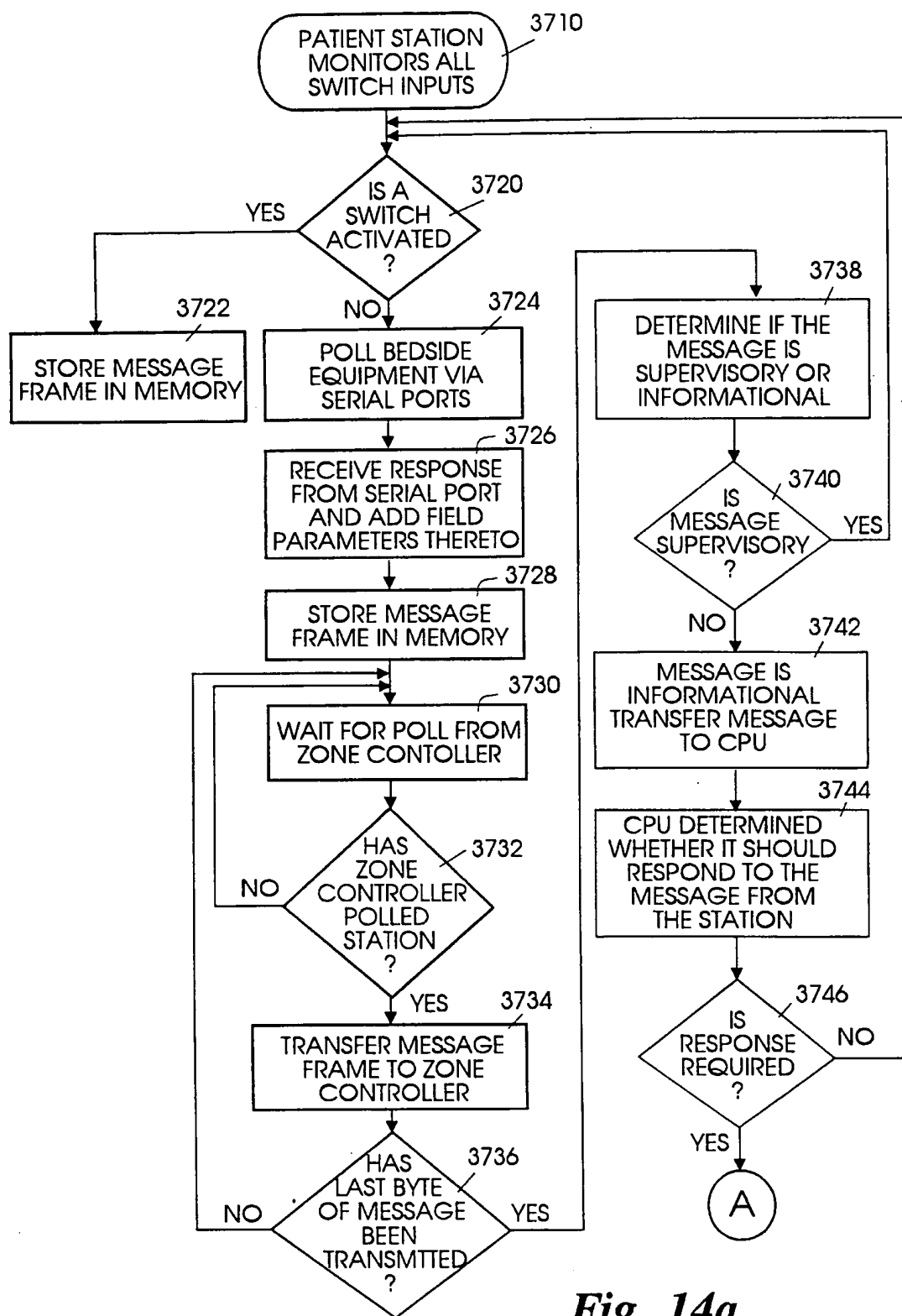


Fig. 12

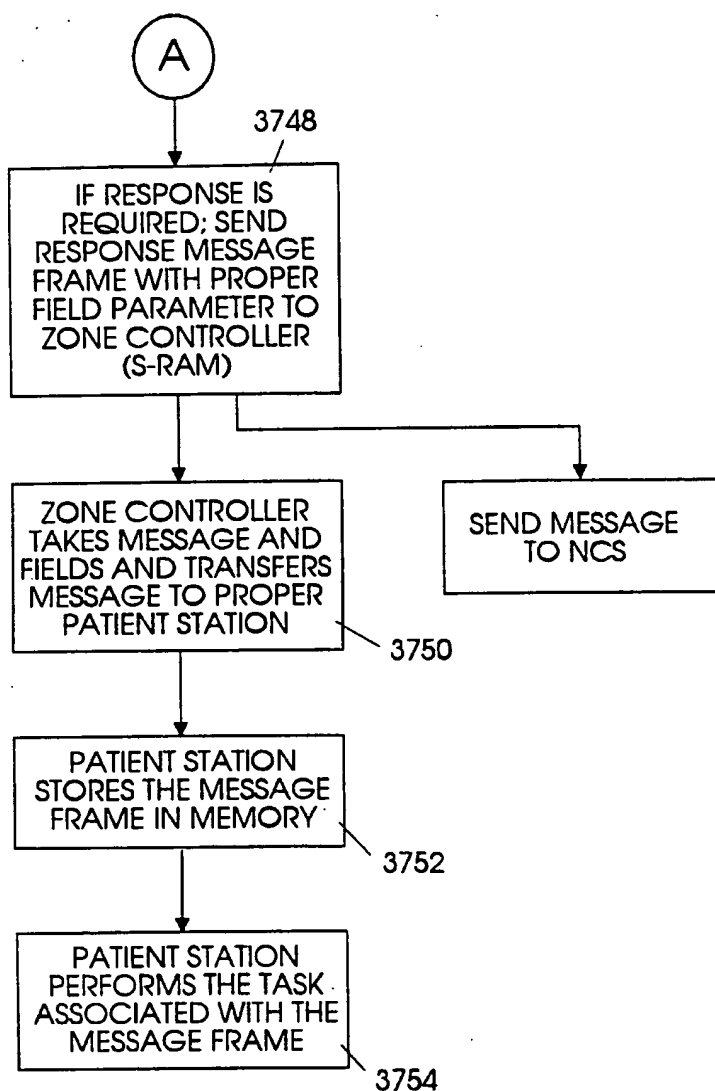


**Fig. 13**

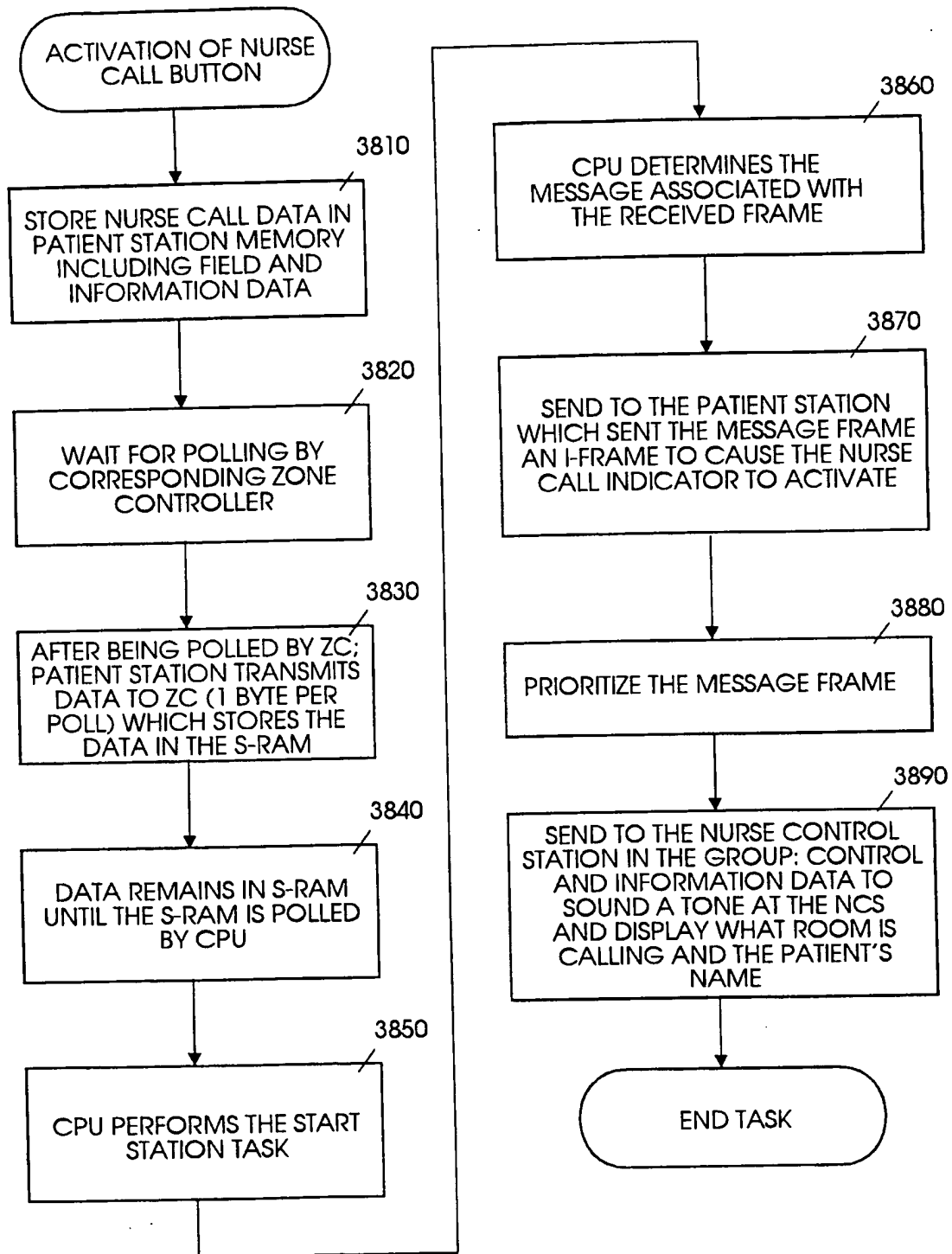
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*Fig. 14a*

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*Fig. 14b*

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**Fig. 15**

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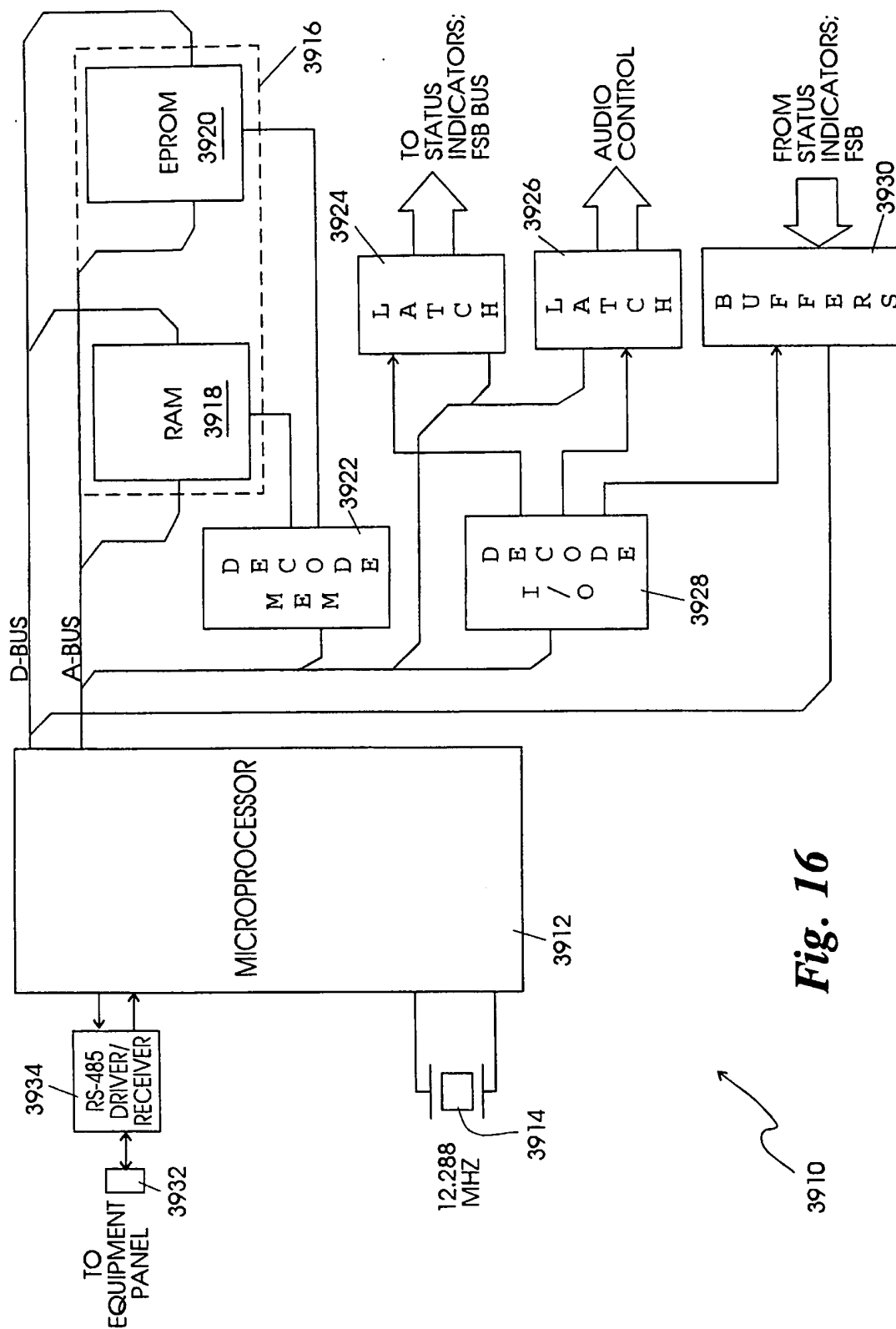
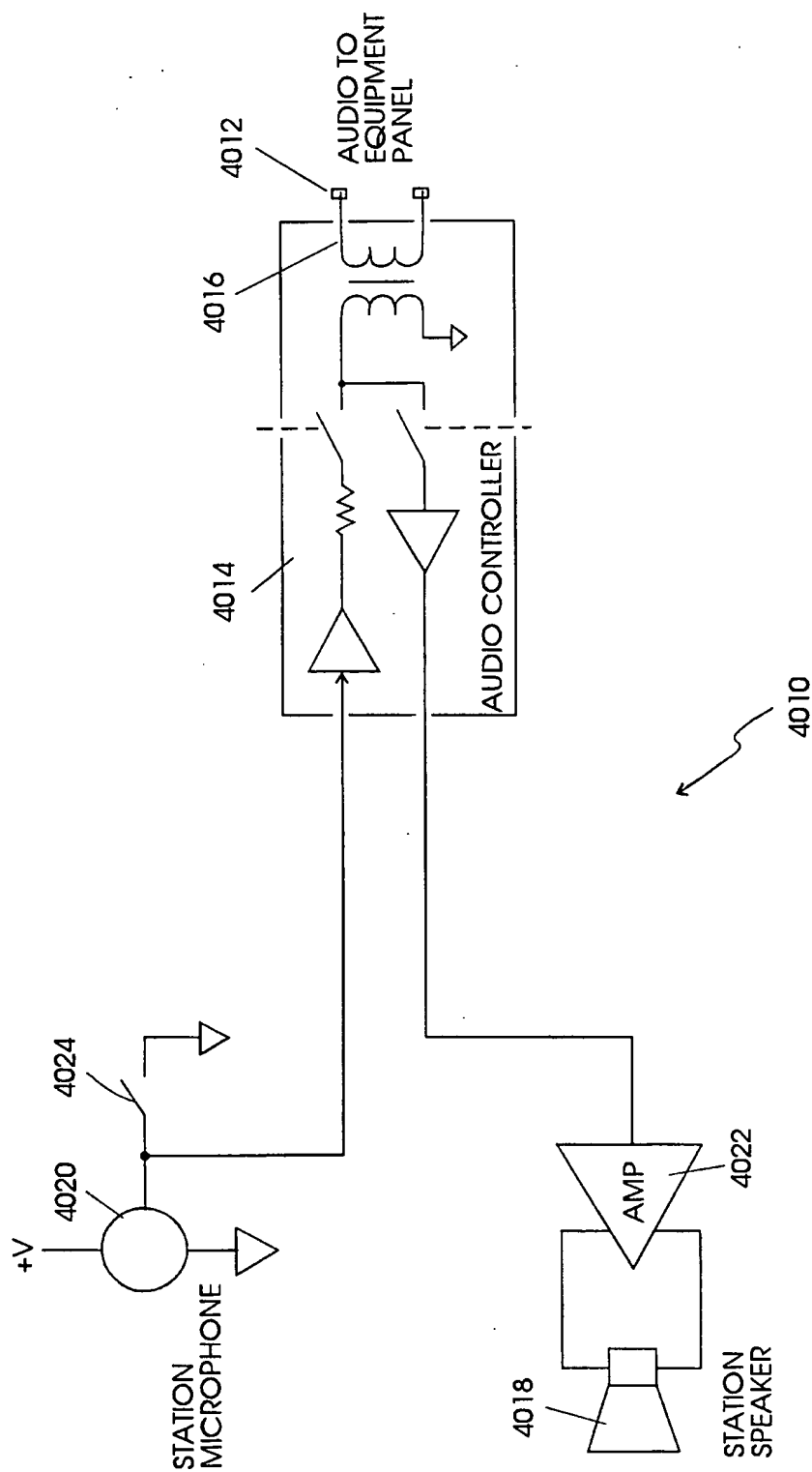


Fig. 16



**Fig. 17**



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Call Indications at Nurse Control Stations

Call Priority Level	Incoming Call Display			Tone Signaling in Pulses Per Minute (PPM)
	Arrow Flash Rate in Pulses Per Minute (PPM)	Room-Bed Displayed on NCS Display 3272	Call Level Displayed on NCS Display 3272	
1 Smoke Detector Call	120	yes-no	SMOKE DETECTOR	120
2 Code Blue Call	120	yes-yes	CODE BLUE	120
3 Staff Assist Call	60	yes-no	STAFF ASSIST	60
4 Emergency Call	60	yes-no	EMERGENCY	60
5 Patient Priority	60	yes-yes	PAT PRIORITY	60
6 Personal Attention	steady	yes-yes	PERSONAL ATTEN	1 @ 4PPM
7 Overtime Call	30	yes-yes	OVERTIME	2 @ 4PPM
8 Cord Removal Call	30	yes-no	CORD REMOVAL	2 @ 4PPM
9 Patient Call	steady	yes-yes	PATIENT CALL	1 @ 4PPM
10 Staff Call	steady	yes-n/a	STAFF CALL	1 @ 4PPM
11 Auxiliary Device Call	30	yes-no	AUX DEV 1 CALL	2 @ 4PPM
12 Auxiliary Device Call	30	yes-no	AUX DEV 2 CALL	2 @ 4PPM

Fig. 18

20 / 40

*Call Indications at Patient Stations*

Call Priority Level	Visual Indications		Tone Signaling in Pulses Per Minute (PPM)	Zone Indicator Assembly Group Indicator Color/Rate (PPM)
	Station Call Placement LED Indicator on Patient Stations (not shown) in PPM	Bed Call Placement LED Indicator on Patient Stations (not shown) in PPM		
1 Smoke Detector Call	120	no	120	Red/120
2 Code Blue Call	120	120	no	Blue/120
3 Staff Assist Call	60	no	no	White/60
4 Emergency Call	no	no	no	White/60
5 Patient Priority	60	60	single tone burst	White/60
6 Personal Attention	steady	steady	single tone burst	White/steady
7 Overtime Call	30	30	no	Grn.-Amb./60-30
8 Cord Removal Call	30	no	no	White/30
9 Patient Call	steady	steady	single tone burst	White/steady
10 Staff Call	n/a	n/a	n/a	White/steady
11 Auxiliary Device Call	30	no	no	White/30
12 Auxiliary Device Call	30	no	no	White/30

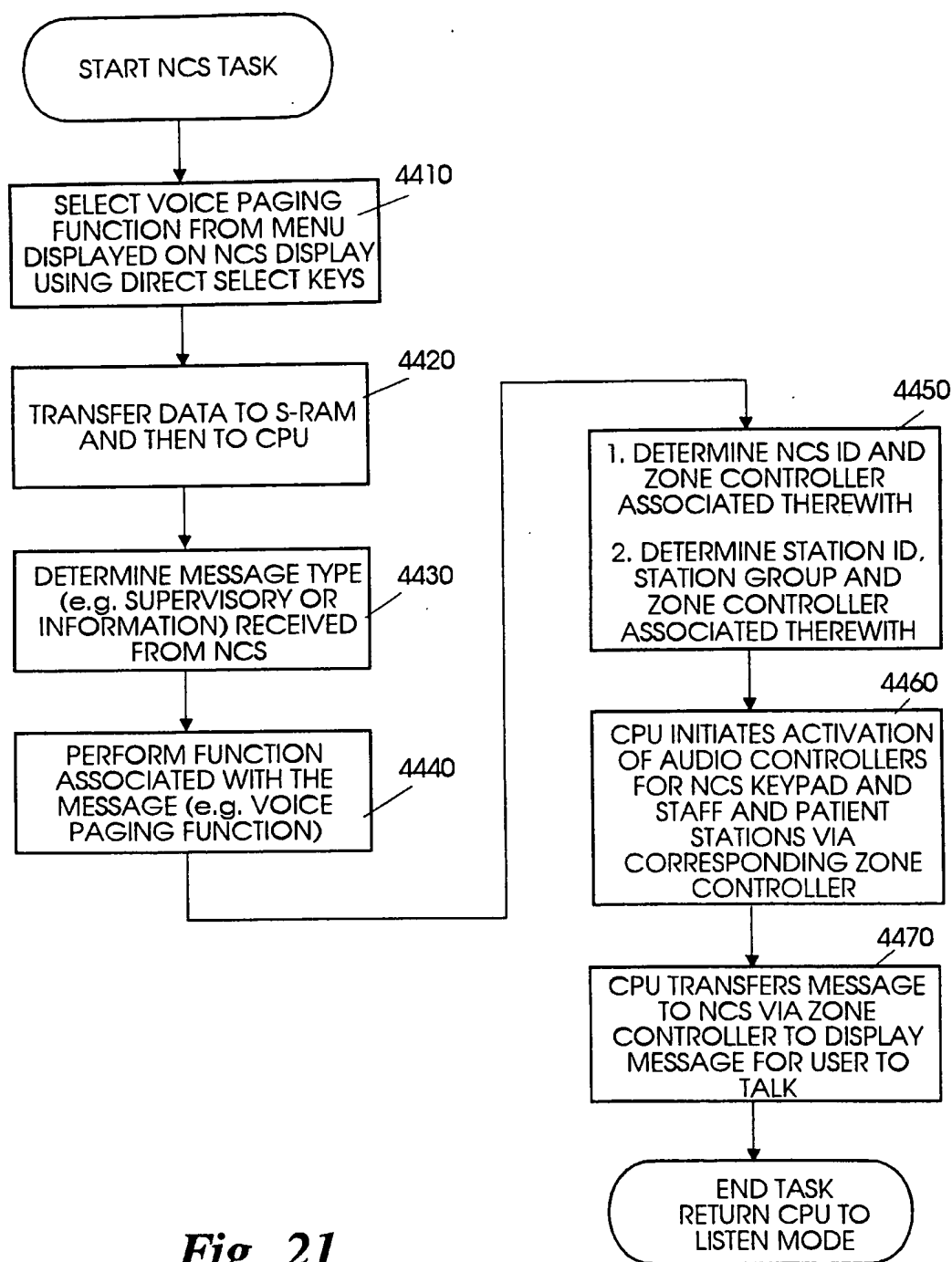
*Fig. 19*

Call Indications at Staff Stations

Call Priority Level	Visual Indications			Tone Signaling Pulses Per Minute (PPM)	Zone Indicator Assembly (3022) Group Indicator Color/Rate (PPM)
	Incoming Call LED Indicator on Staff Station (not shown) (PPM)	Room-Bed Displayed on Staff Station Display 2422	Call Level Displayed on Staff Station Display 2422		
1 Smoke Detector Call	120	yes-no	SMOKE DETECTOR	120	Red/120
2 Code Blue Call	120	yes-yes	CODE BLUE	120	Blue/120
3 Staff Assist Call	60	yes-no	STAFF ASSIST	60	White/60
4 Emergency Call	60	yes-no	EMERGENCY	60	White/60
5 Patient Priority	60	yes-yes	PAT PRIORITY	60	White/60
6 Personal Attention	steady	yes-yes	PERSONAL ATTEN	1 @ 4PPM	White/steady
7 Overtime Call	30	yes-yes	OVERTIME	2 @ 4PPM	Grn.-Amb./60-30
8 Cord Removal Call	30	yes-no	CORD REMOVAL	2 @ 4PPM	White/30
9 Patient Call	steady	yes-yes	PATIENT CALL	1 @ 4PPM	White/steady
10 Staff Call	steady	yes-n/a	STAFF CALL	1 @ 4PPM	White/steady
11 Auxiliary Device Call	30	yes-no	AUX DEV 1 CALL	2 @ 4PPM	White/30
12 Auxiliary Device Call	30	yes-no	AUX DEV 2 CALL	2 @ 4PPM	White/30

Fig. 20

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*Fig. 21*

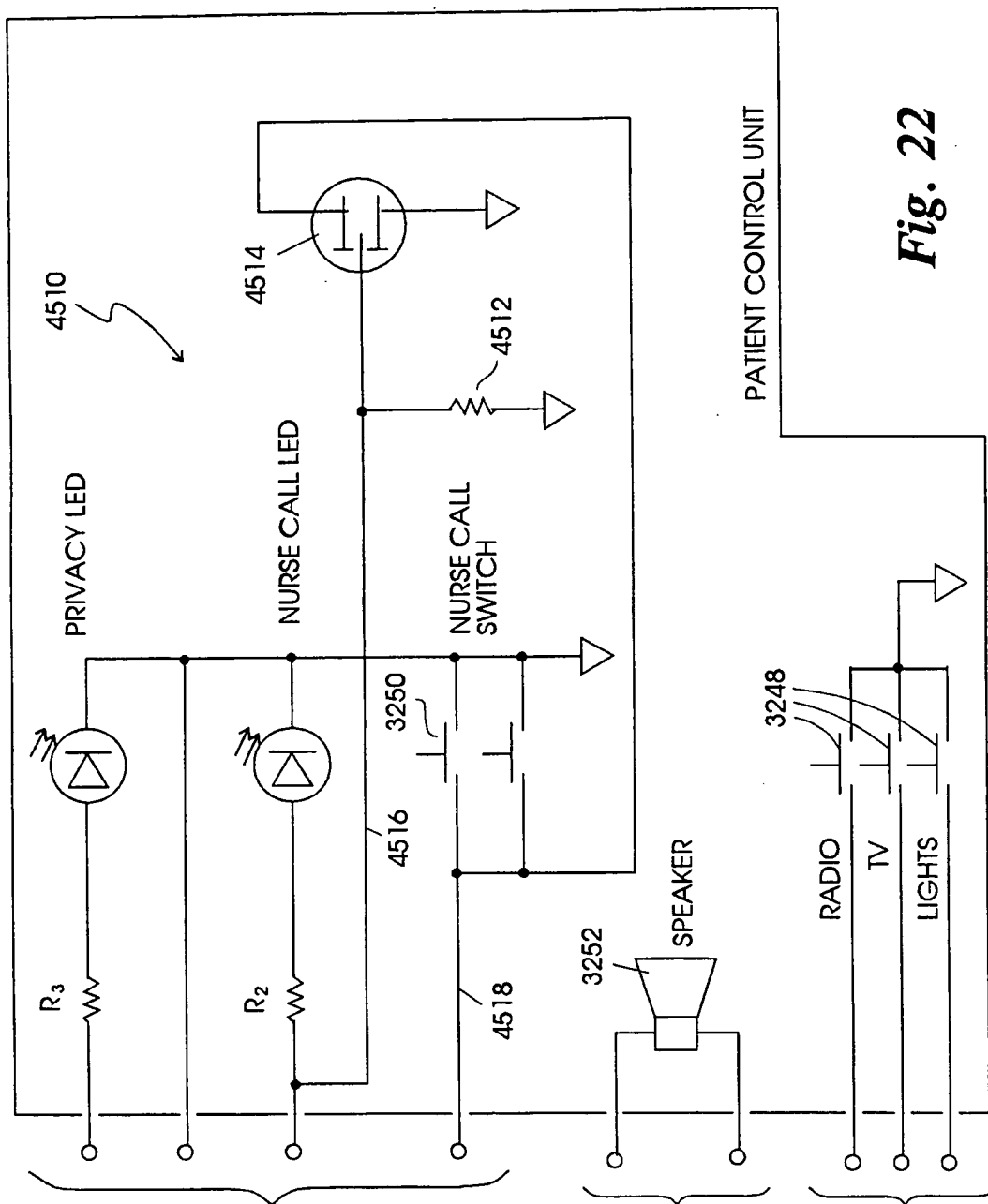
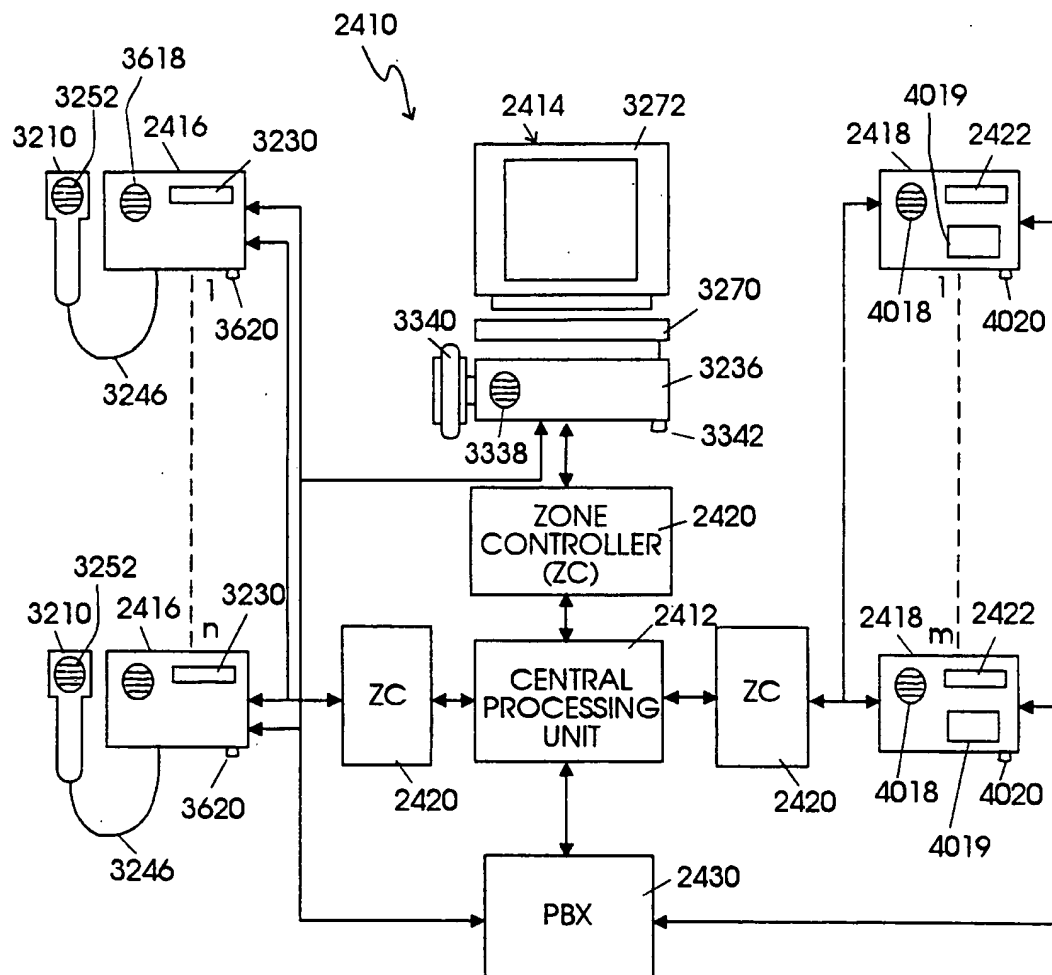


Fig. 22

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**Fig. 23**

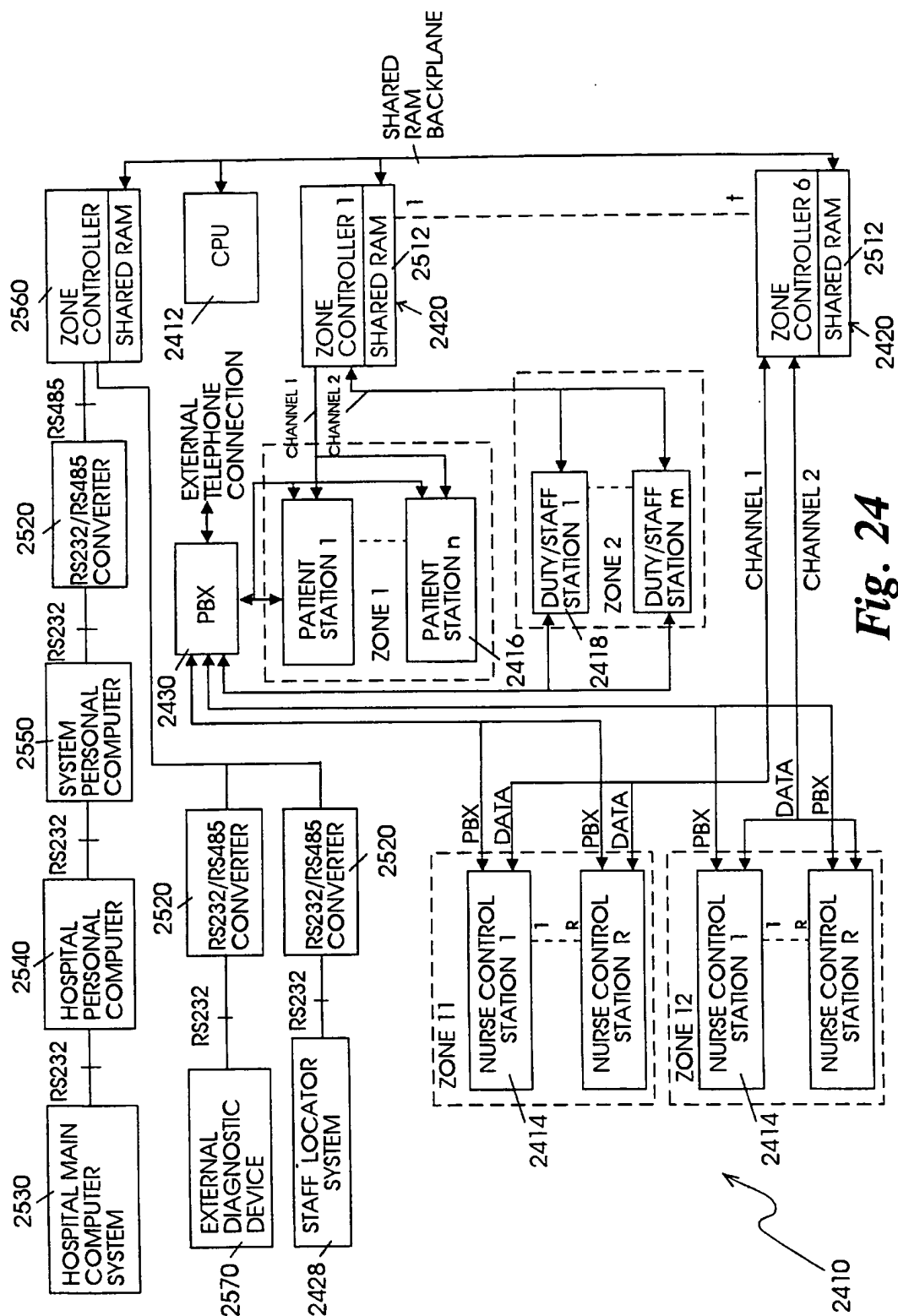


Fig. 24

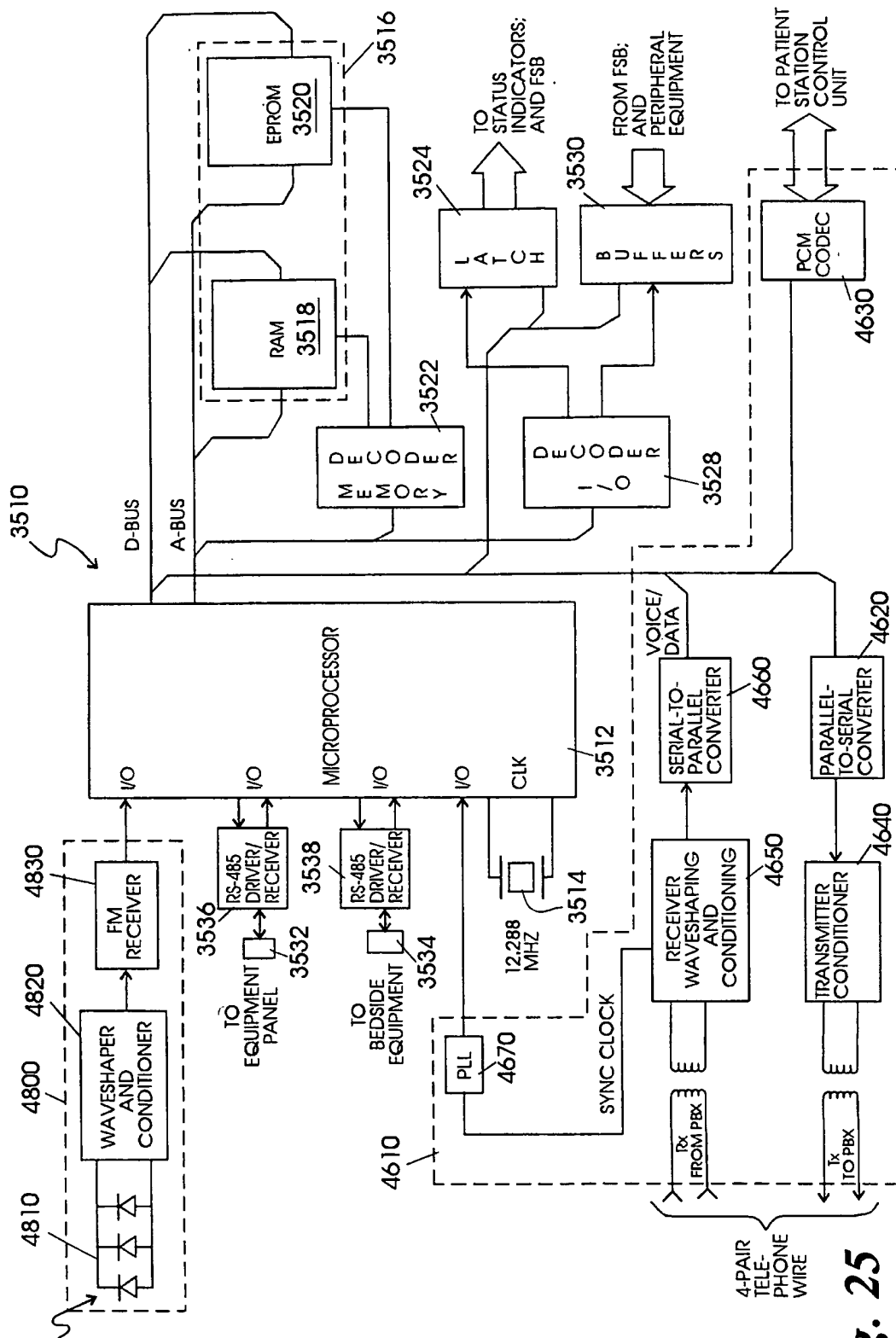


Fig. 25



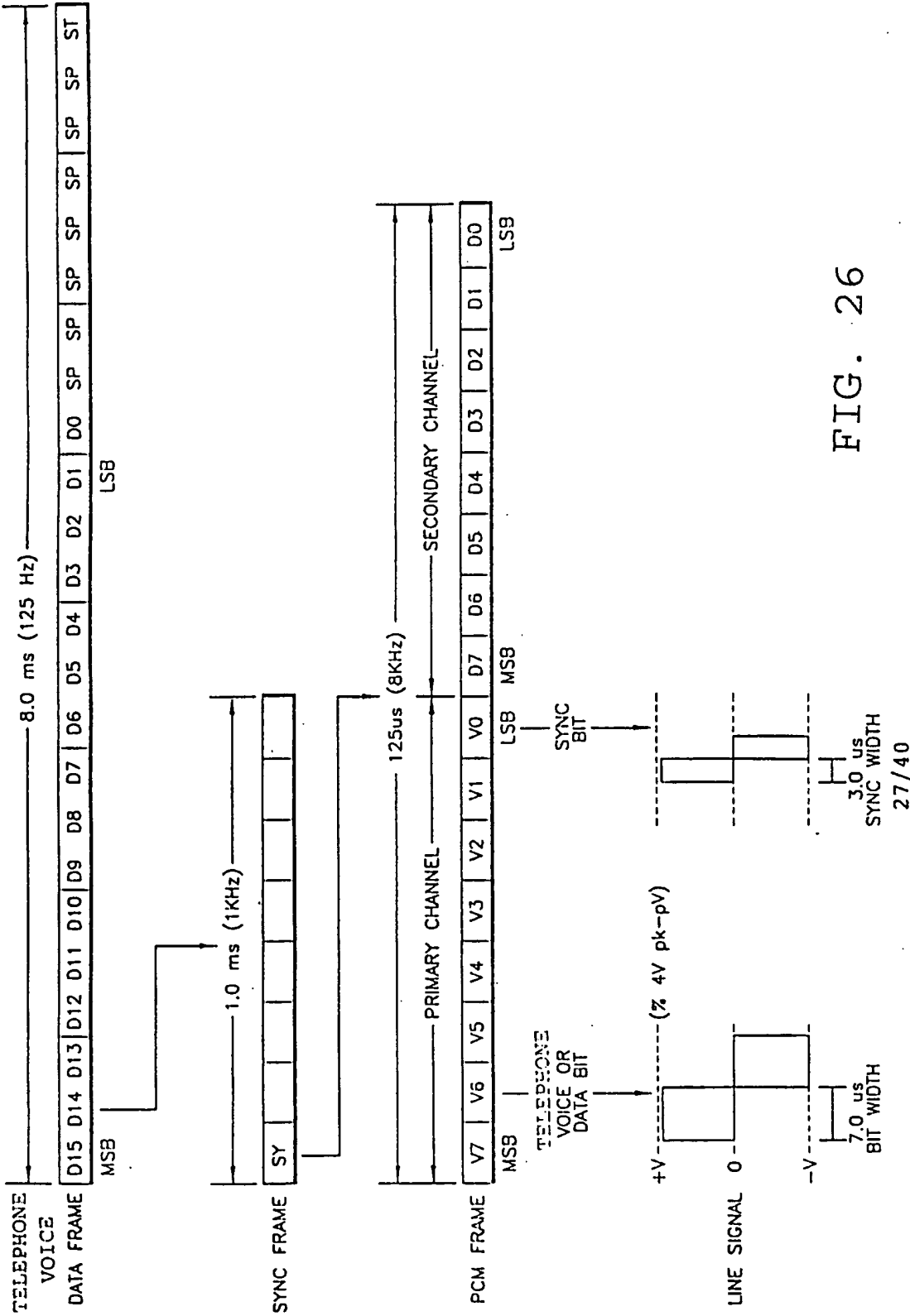
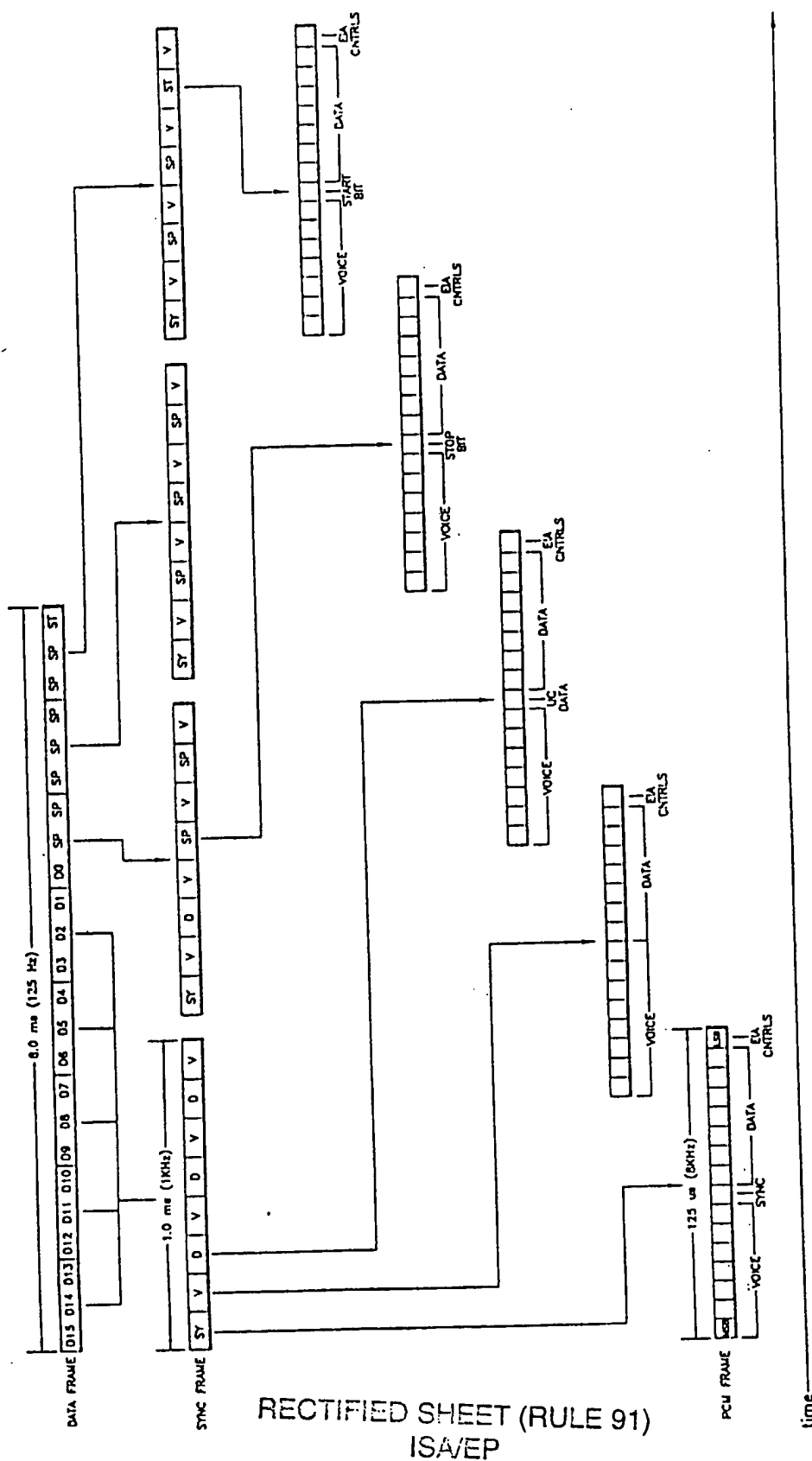


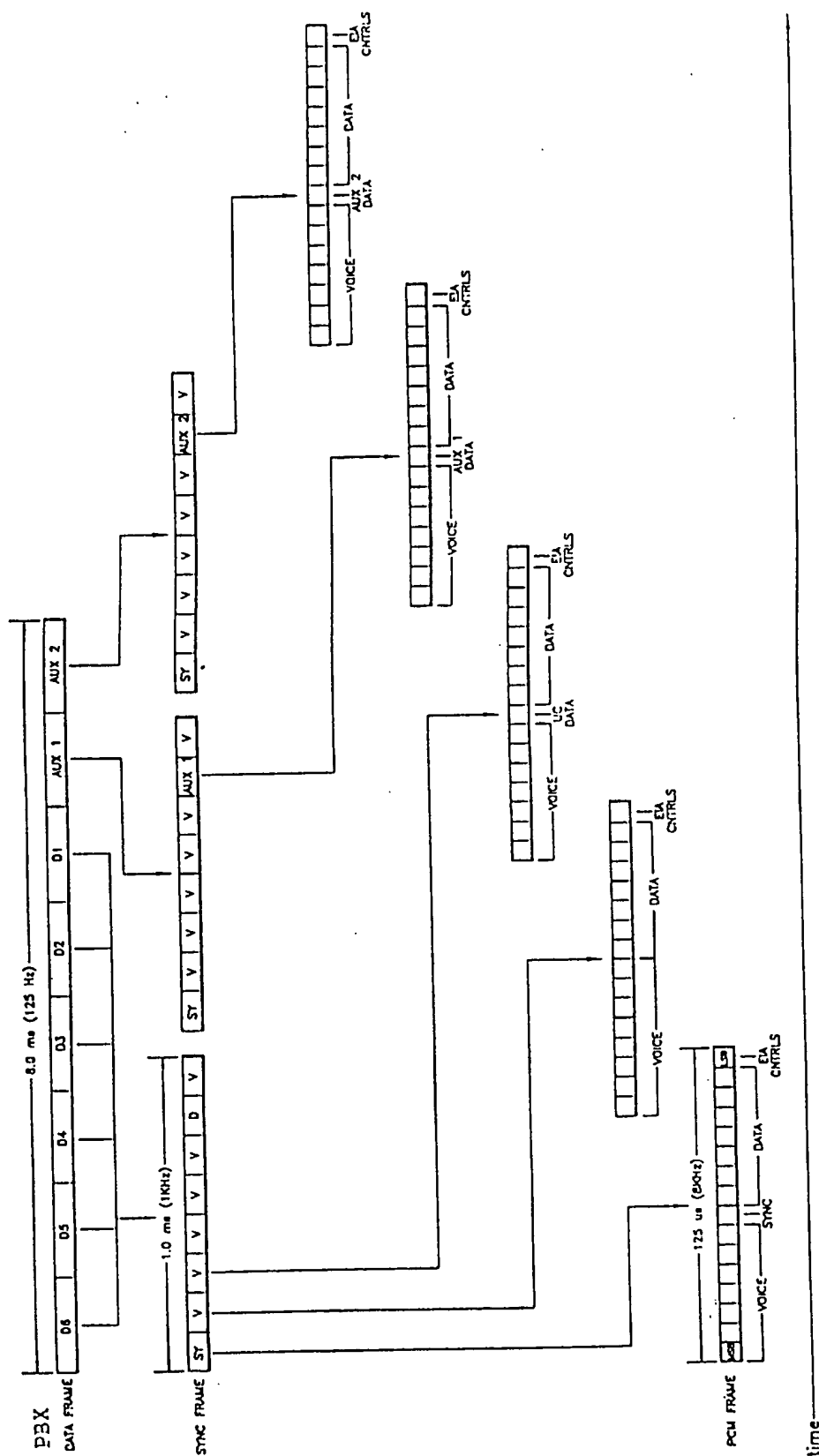
FIG. 26



RECTIFIED SHEET (RULE 91)  
ISA/EP

FIG. 27

DATA FRAME FORMAT AND TIMING TO PBX



DATA FRAME FORMAT AND TIMING TO TELEPHONE

FIG. 28

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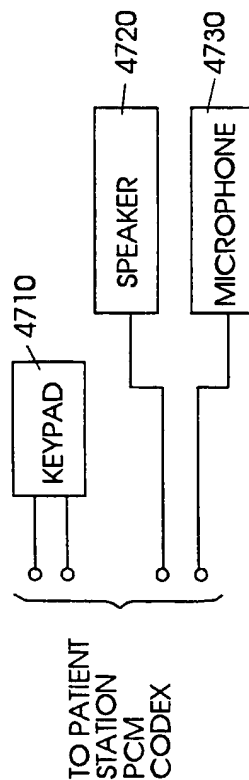
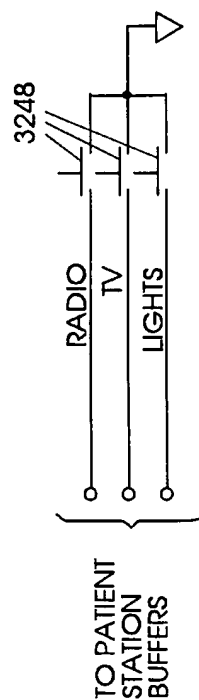
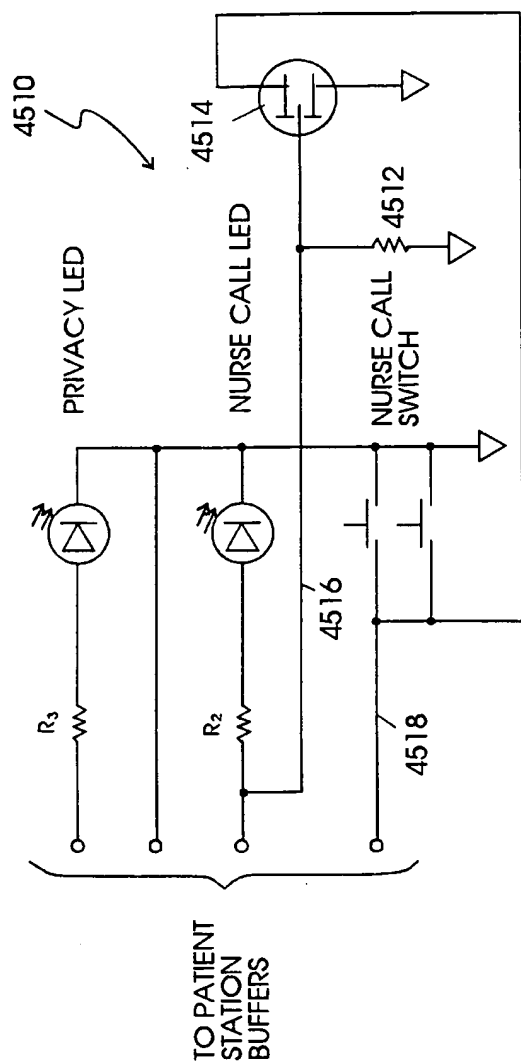


Fig. 29

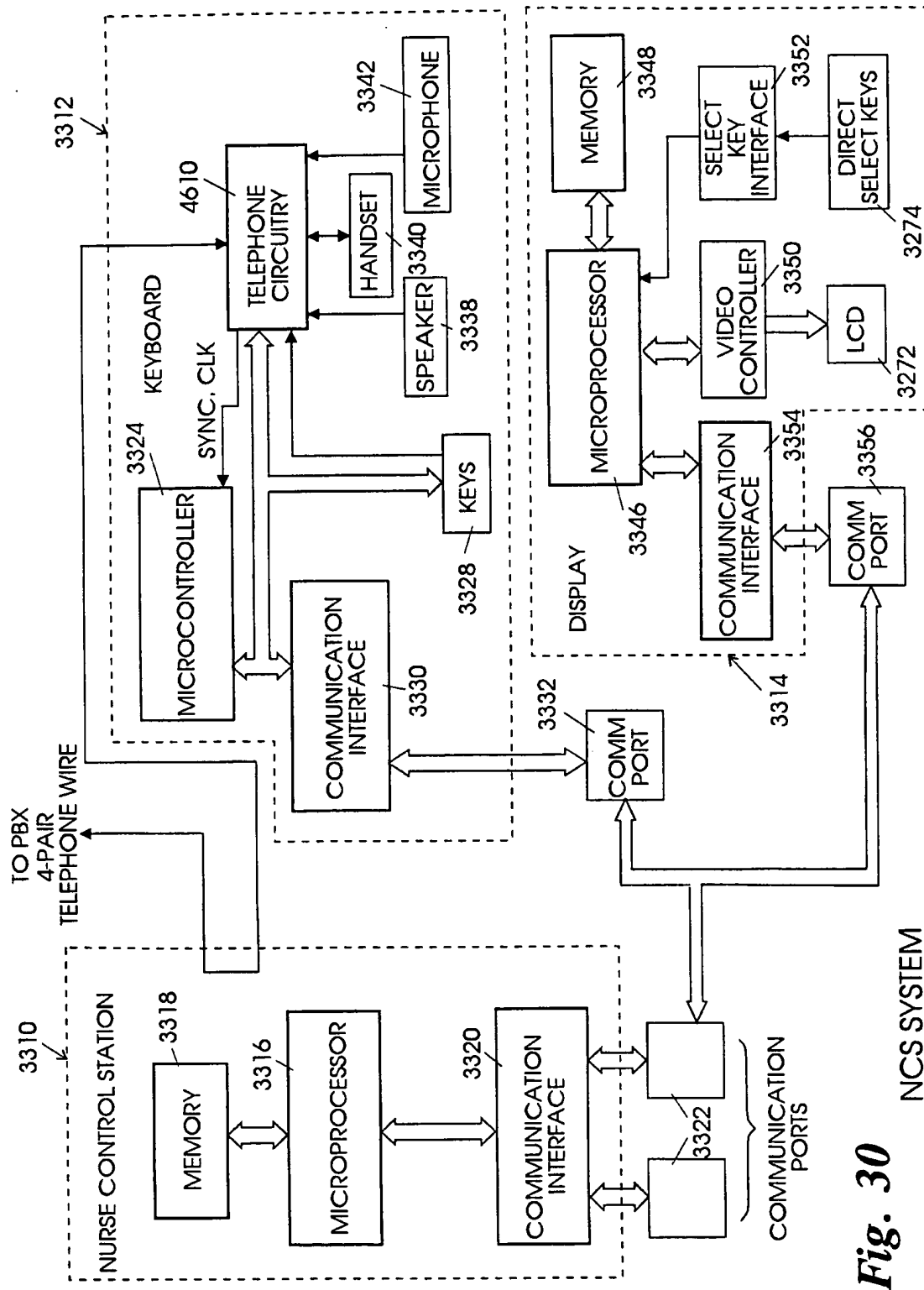
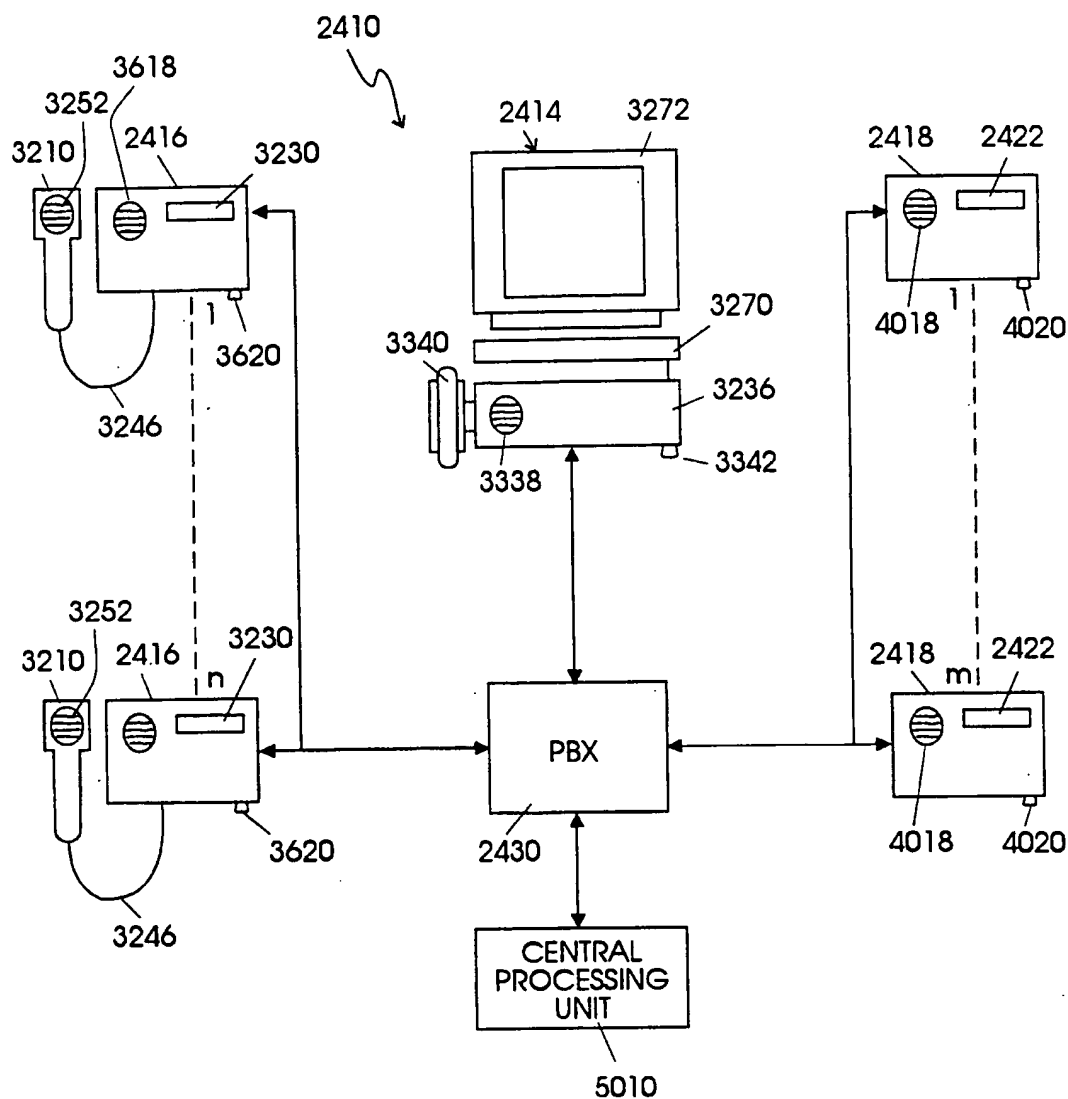


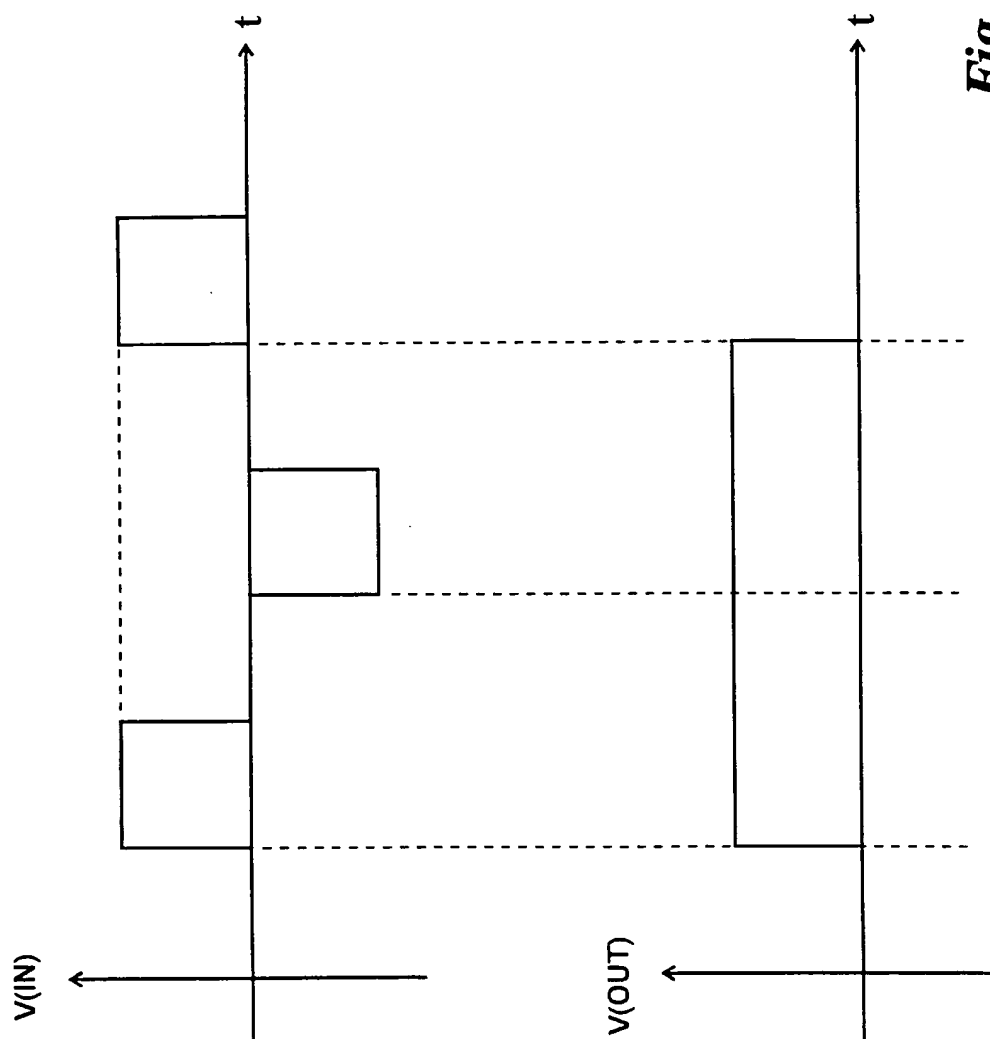
Fig. 30

NCS SYSTEM

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**Fig. 31**

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**Fig. 32**

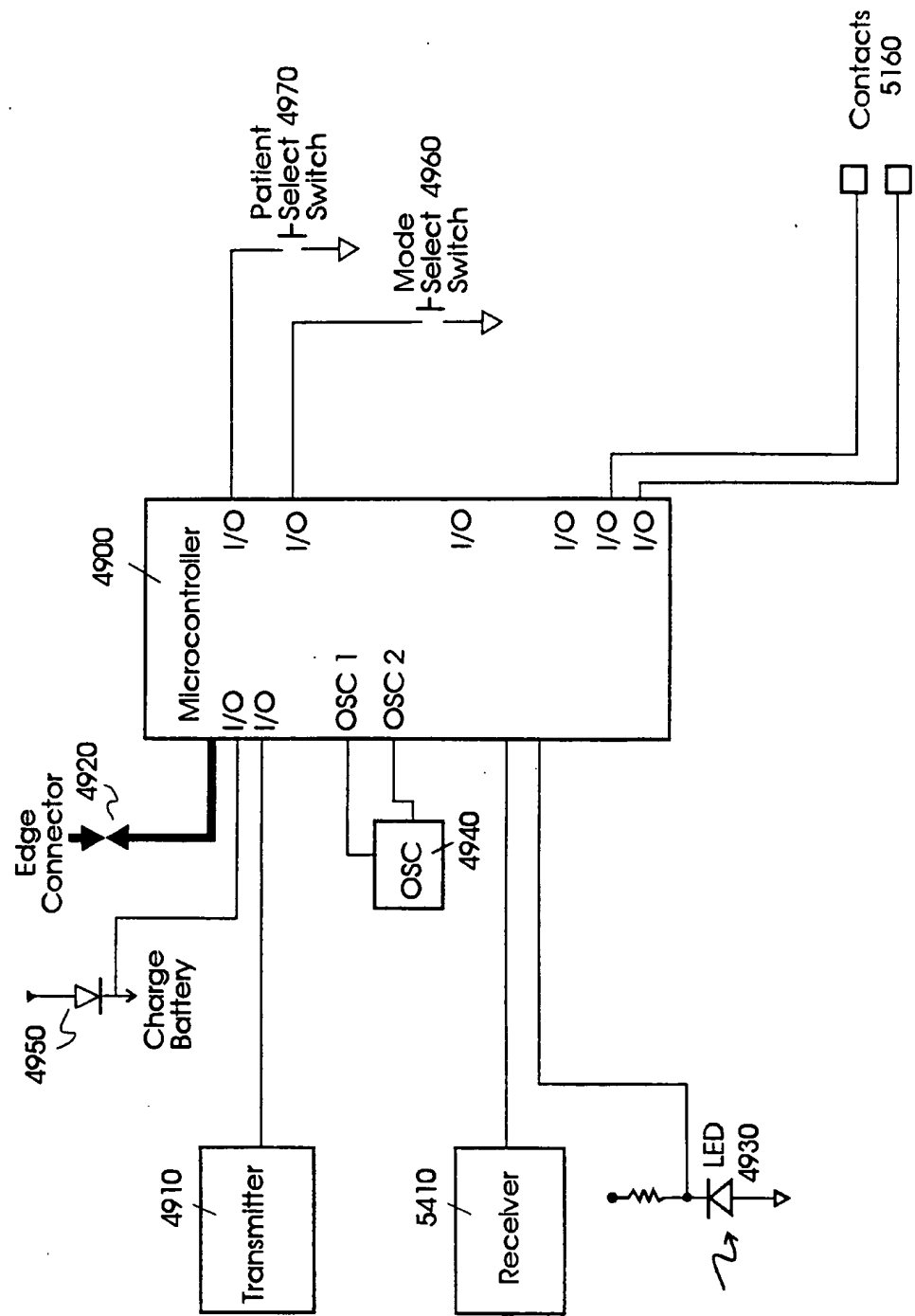
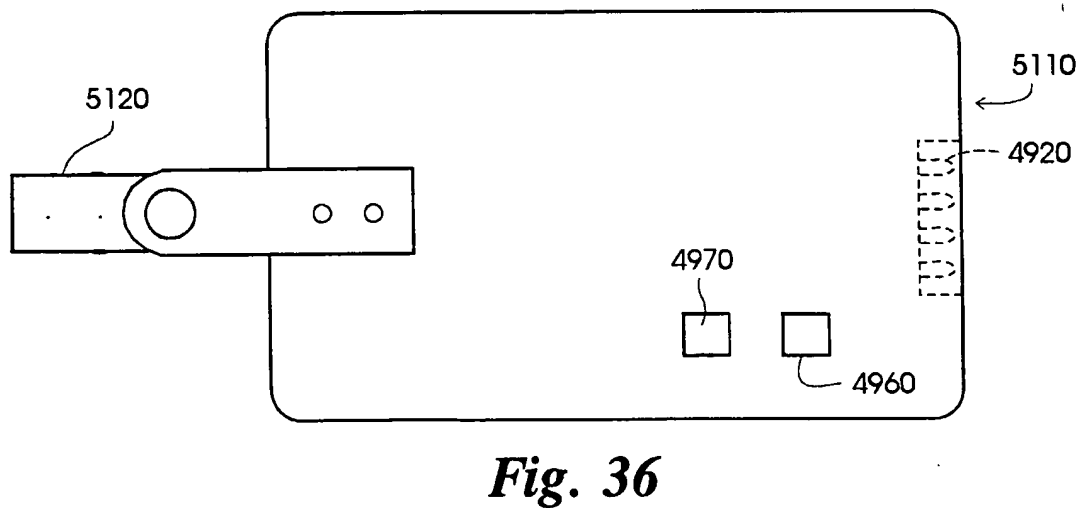
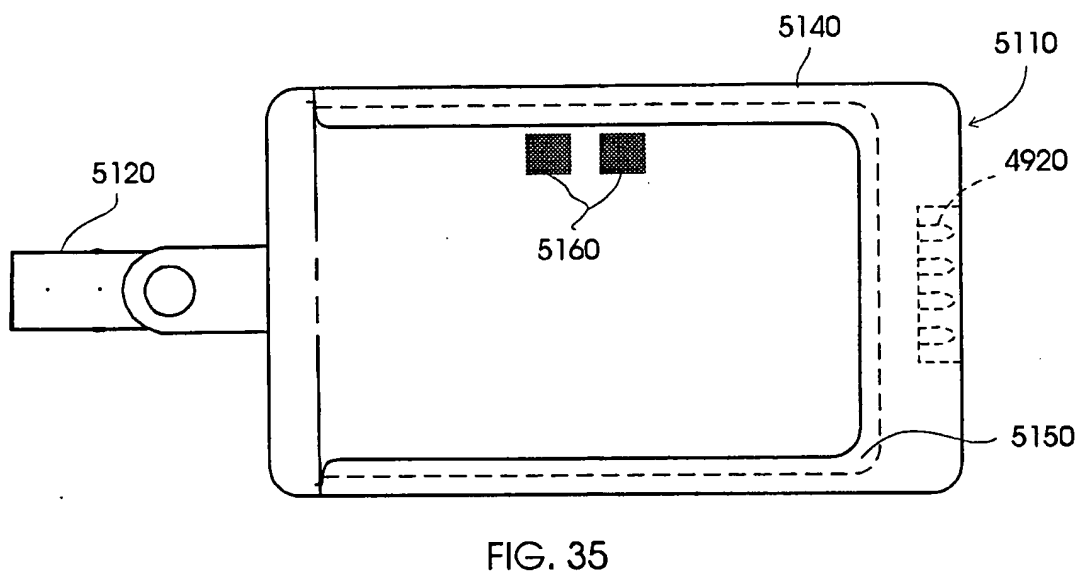
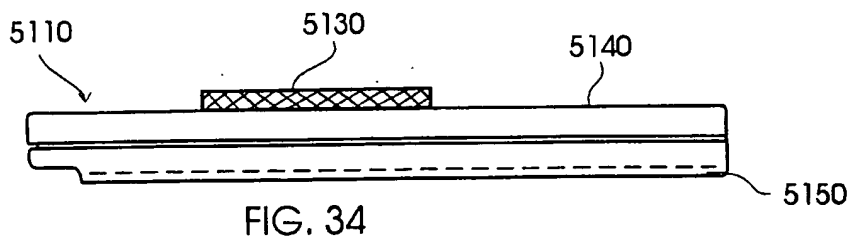


Fig. 33

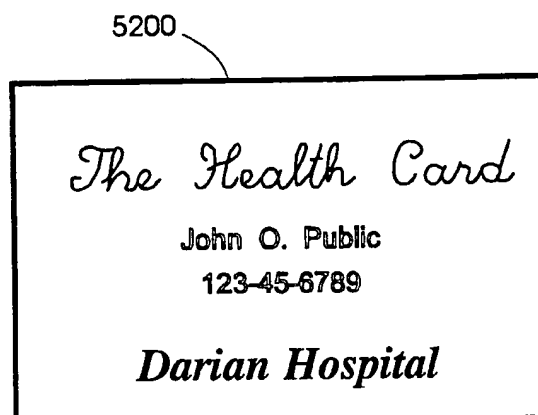
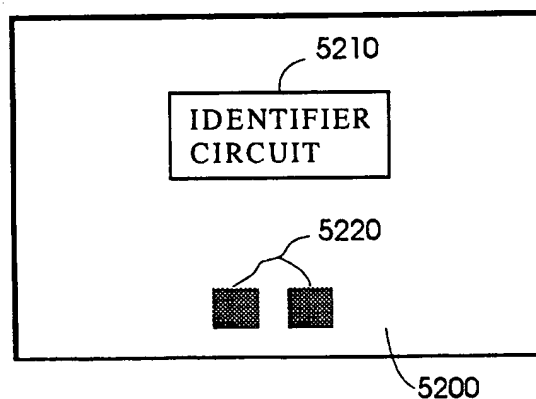
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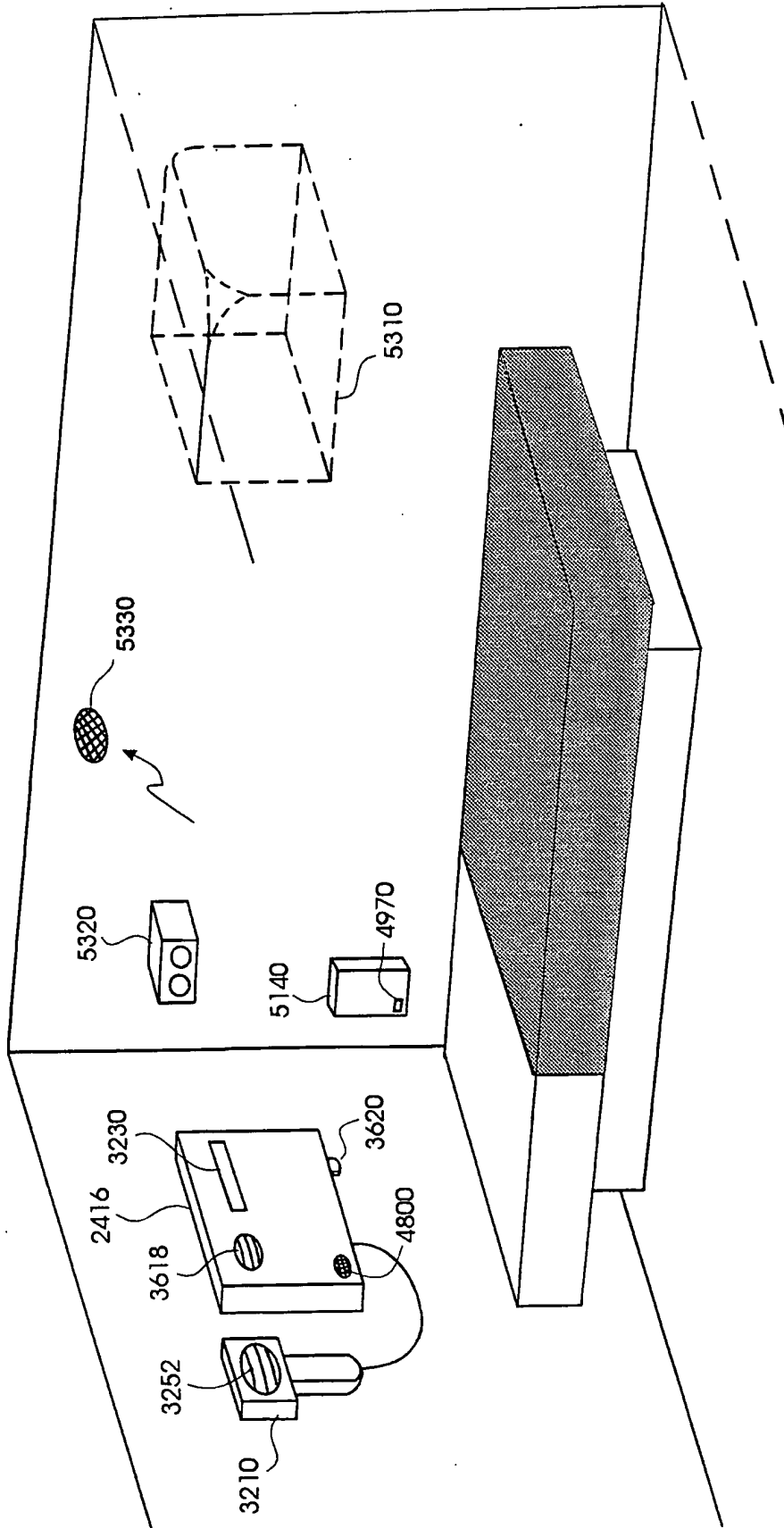


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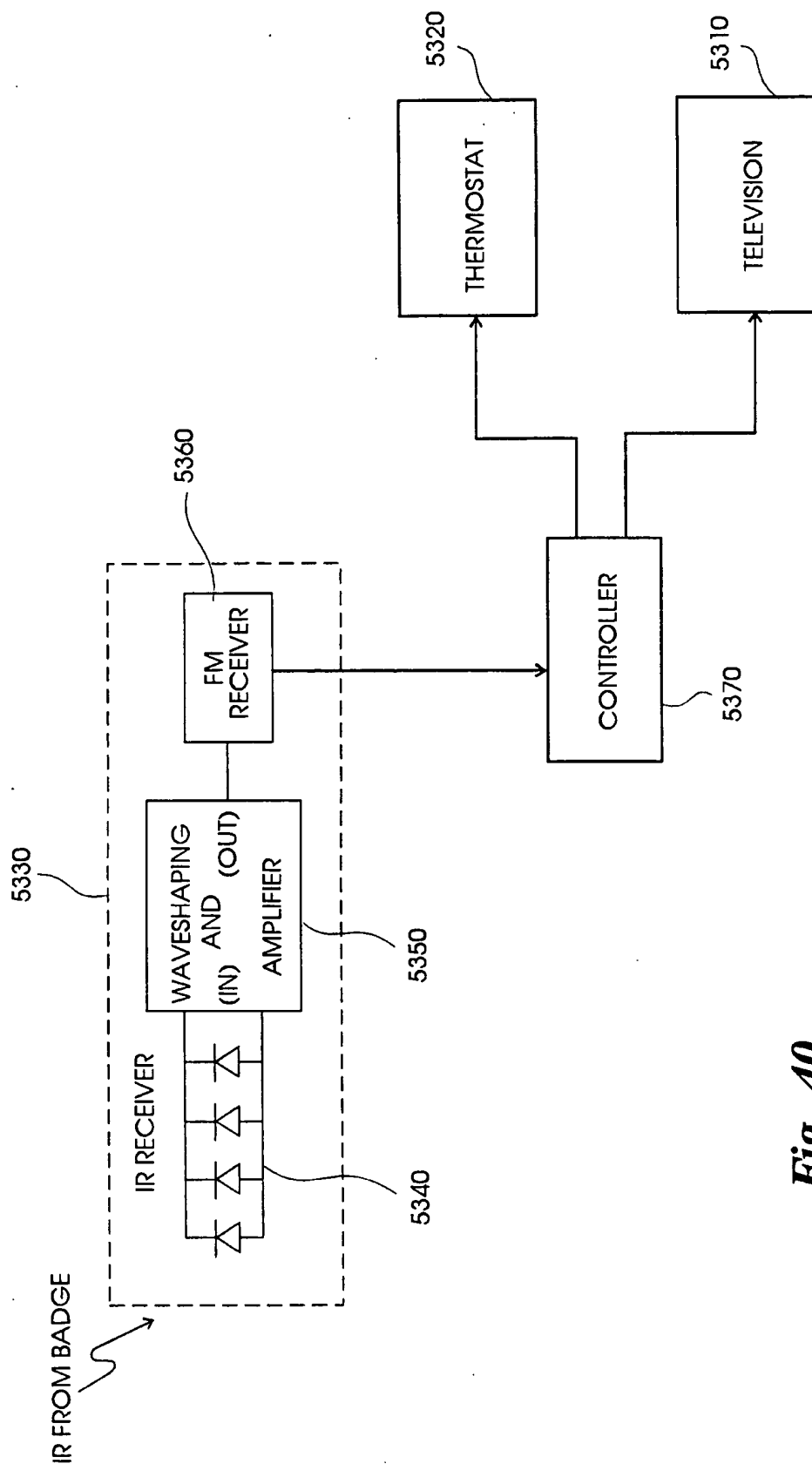


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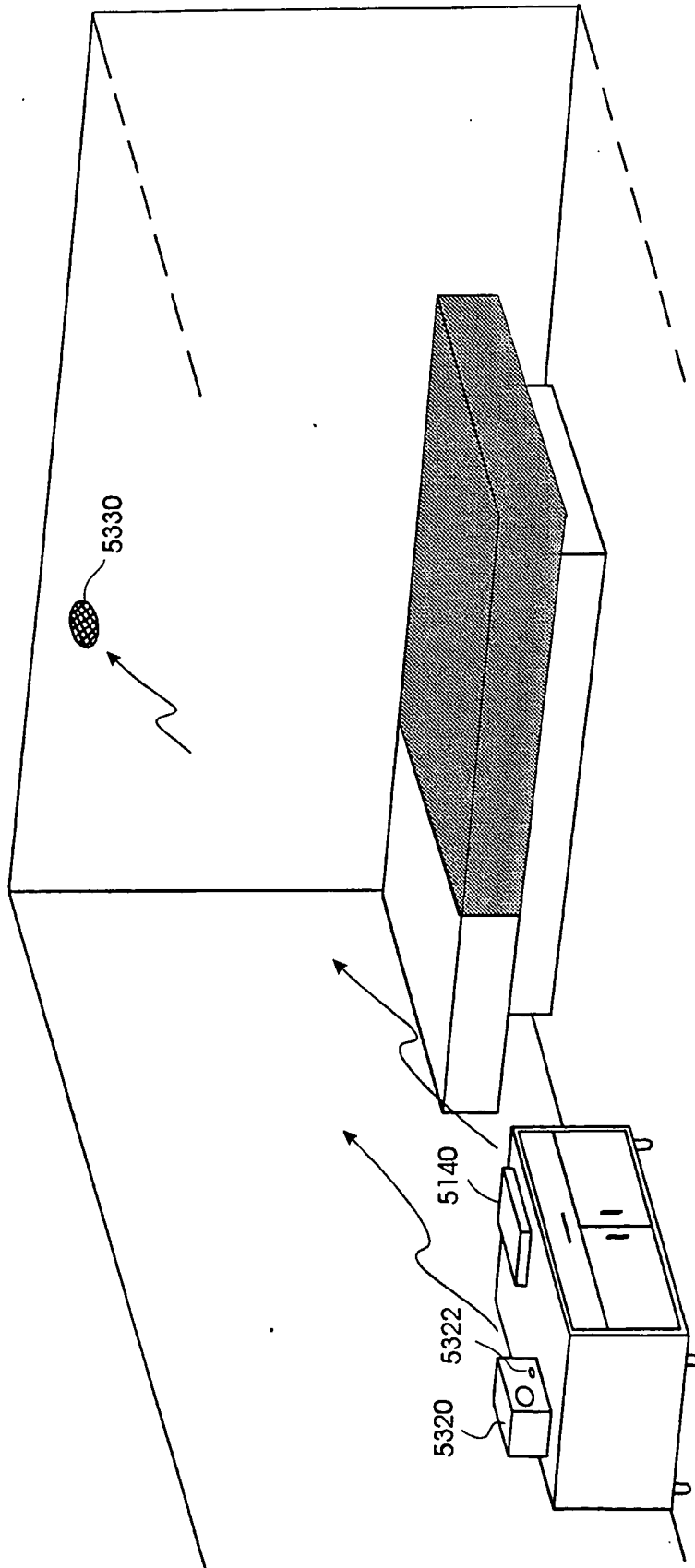
**Fig. 37****Fig. 38**



**Fig. 39**

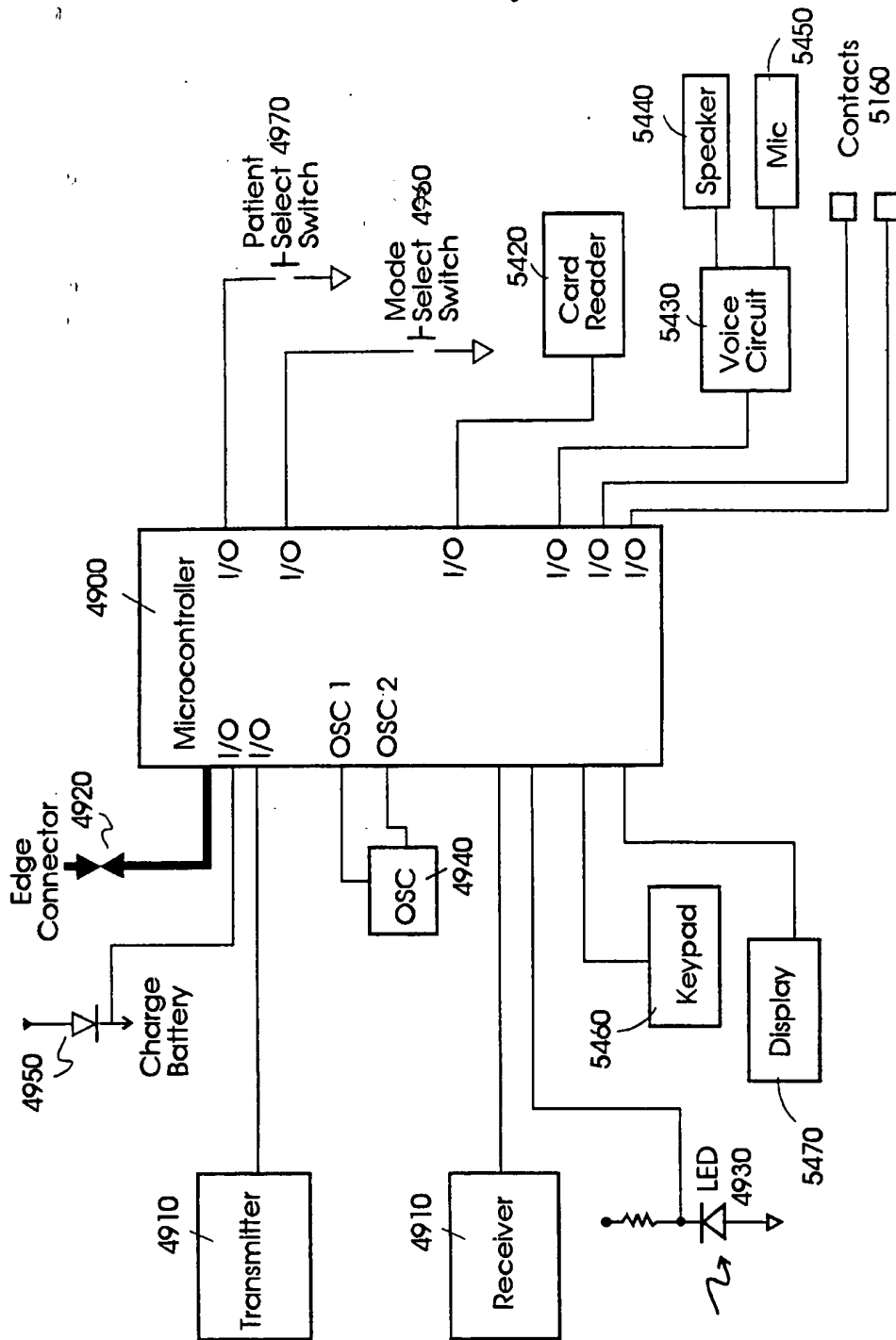


**Fig. 40**



**Fig. 41**

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**Fig. 42**

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